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SHIPS SUPPLY SUPPORT STUDY (S4)

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Office of the Chief of Naval Operations
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13. ABSTRACT

As indicated in the CNO Study Directive, the objective of the study was to "define, develop and propose an automated model by which supply support dollar outlays may be related to fleet capability". A set of simulators representing the supply echelons supporting the Sixth Fleet (except aviation) were developed. Output from the simulators was combined and synthesized to produce a single system-wide Requisition Response Time value. An additional model was designed that permits conversion of this measure into Supply Response Time (SRT) related to a particular maintenance action. Finally, the SRT is combined with the traditional MTBF and MTTR parameters into an equipment Operational Availability (A_o) expression. (U)

Queuing models describing requisition processing operations were incorporated into an advanced version of the simulation. This version serves as a management device for investigating how supply response time varies with changes in supply system resources. Experiments were conducted to answer questions about material availability and resource allocation.

The report includes a set of recommendations for reducing supply system response time as well as potential future uses of the S^4 models.

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Ship Supply Support Study (S^4)						
Supply Response Time						
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Resource Allocation						
Throughput time						
Supply Availability						
Queuing Analysis						
Requisition Response Time						

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Subj: Ships Supply Support Study Report, promulgation of

Encl: (1) Ships Supply Support Study Report

1. Enclosure (1) forwards the report of the Ships Supply Support Study, which was undertaken to define, develop and propose an automated model by which supply support dollar outlays may be related to fleet capability.

2. The study has produced a series of computer programs described in enclosure (1), which model the supply performance of ships in the SIXTH Fleet in such a way as to estimate the change in performance resulting from changes in inventory and processing resources. These programs can be used by elements of the support sys m to investigate proposed changes in methods or levels o. support.

3. In demonstrating the feasibility of the computer models and in analyzing data gathered for simulation purposes, the study group developed data to support several recommendations for immediate improvement. Among these was persuasive evidence to justify implementing an externally developed proposal for reducing the number of technical override items included in ships allowance lists. It is considered of interest that the potential first year savings ($2M) from this single recommendation will more than defray the total expense of the study.

4. The recommendations in Chapter VIII need not be implemented immediately. However, commands are encouraged to take early action on recommendations limited to activities within the command. Commands wishing to comment on any of the recommendations may do so to OP-41 within 60 days of the date of this letter, after which specific instructions covering each recommendation not already implemented will be issued. (It should be noted that, in other action, the Vice Chief of Naval Operations has already partially implemented Recommendation 2 by directing extention of S^4 methodology to aviation support for the SIXTH and SEVENTH Fleets.)

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I. INTRODUCTION AND SUMMARY

The Ships Supply Support Study (S³), started in July 1971, is a part of the CNO Study Program directed by the Systems Analysis Division (OP-96) of the Office of the Chief of Naval Operations. Sponsored by the Material Division (OP-41), the study has been executed by the Naval Supply Systems Command (principally through the Fleet Material Support Office), several organizations within the Atlantic Fleet, the Maintenance Support Office and numerous other Naval and commercial organizations (see Appendix D).

The purpose of the study, as indicated in the Study Directive (see Appendix A), is to "define, develop and propose an automated model by which supply support dollar outlays may be related to fleet capability." To make the study more manageable and to reduce disruption of the operating forces, it was limited to the general purpose forces of the Sixth Fleet, less aviation. Thus, support of aircraft (but not aircraft carriers) and of ballistic missile submarines (but not other submarines) is excluded. In terms of commodities, the study is limited to repair parts and components needed for equipment maintenance (see Table II-1) and hence ignores the supply of fuel, ordnance, provisions, clothing, medicine and housekeeping supplies.

The computer programs built during the study calculate three indicators of performance used as surrogates for "fleet capability." These are:

° Requisition response time -- the time elapsing between a shipboard mechanic's request for a part needed in a corrective maintenance action and the mechanic's receipt of material.

° Supply response time -- the time elapsing between the mechanic's request and the receipt of <u>all</u> parts needed to complete a corrective maintenance action.

° Equipment operational availability -- the fraction of time, under steady state conditions, that an equipment is capable of operation, even though it may not be called upon to operate.

The relationships among these indicators are described in Section V-F.

For purposes of the study, the material support system is defined very broadly to include the ship's storeroom, the part or component manufacturer, and all the intervening organizations, including the necessary communication, transportation, requisition processing, materials handling, and repair-for-stock functions. Figure I-1 portrays the major supply levels and supply sources which may be involved in satisfying a given Sixth Fleet end-use requisition. Not all levels are involved in the satisfaction of a particular end-use requisition, chiefly because (a) most requisitions are satisfied in the first few levels and (b) routine requisitions are not handled by those levels (namely, II, IV, and VI), activated solely for emergency purposes - satisfaction of NORS, ANORS, or CASREPT requisitions.

SUPPLY LEVELS

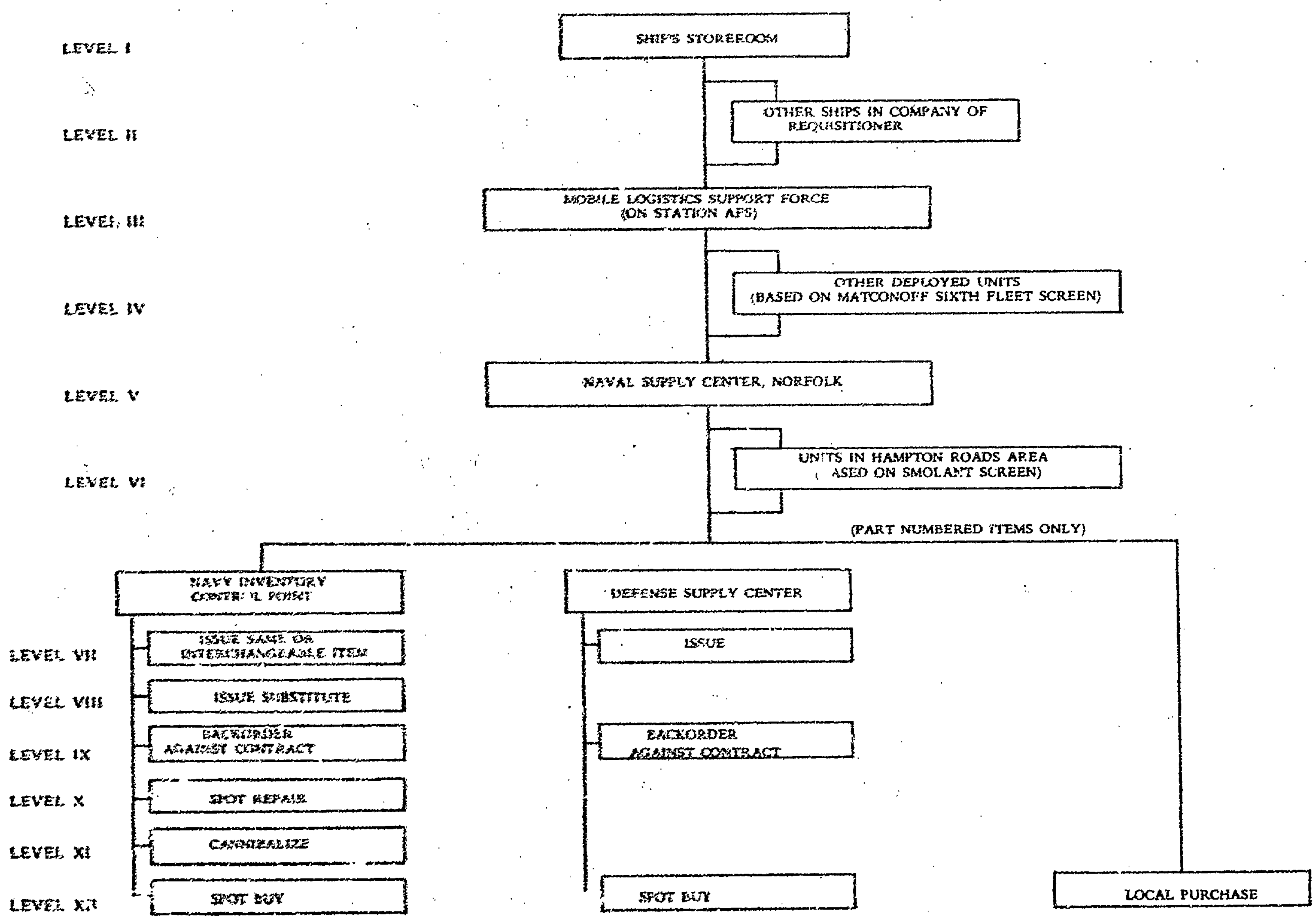


FIGURE I-1

In the computer simulators, described below, only eight levels, or echelons, were simulated. These are: the ship's storeroom, the MATCONOFF screening, the AFS, NSC Norfolk, and referral, backordering, spot-buying and spot-repairing by the inventory control point.

The current performance of the Sixth Fleet's material support is a function of the resources available - inventory, personnel, computers, communication and transportation systems - and of the operating doctrines in force - replenishment rules, sailing schedules, flight frequencies, batching and scheduling rules. These are described in detail in Chapter III and Appendix C. Further details are available through the Technical Memoranda issued during the course of the study and indexed in Appendix F.

It is the job of the computer programs designed and built during the S⁴ study to model the Sixth Fleet's material support system as accurately as time and available data permit. The major outputs of the programs are:

° The gross supply availabilities attainable at each of eight echelons for each of 15 classes of material if specified inventories are held at each location.

° The time required for a requisition and the material resulting therefrom to complete the several legs of their journey from the mechanic to the echelon having stock and back to the mechanic (i.e., the echelon's throughput time).

° The requisition response time as the mechanic views it, given that each echelon supplies a part of the mechanic's total needs.

° The supply response time - the time required to collect all the parts needed for a corrective maintenance action.

° The operational availability, or up-time, of a particular nomenclature of equipment based on the supply response time developed above plus other characteristics.

Figure I-2 displays the interconnections, flow of data, and general outputs of the five simulators and analyzers developed in the study. The Afloat and CONUS Inventory Simulators require as inputs the demands imposed on each echelon, the inventories available at each echelon and the policies employed in satisfying demands and replenishing stock. The computer first combines these inputs in a stream of issue and receipt events covering thousands of items and several years and then analyzes the events to estimate resulting inventory levels, resupply and issue workload, and gross supply availability.

The Process Analyzer, using engineered or estimated time standards, models of requisition and material flow within an organization, and various doctrines concerning batching, scheduling, and transporting, produces a statement of the probability that a requisition or material will be completely processed through an organization in a specified time,

SCHEMATIC OF SUPPLY SYSTEM SIMULATOR

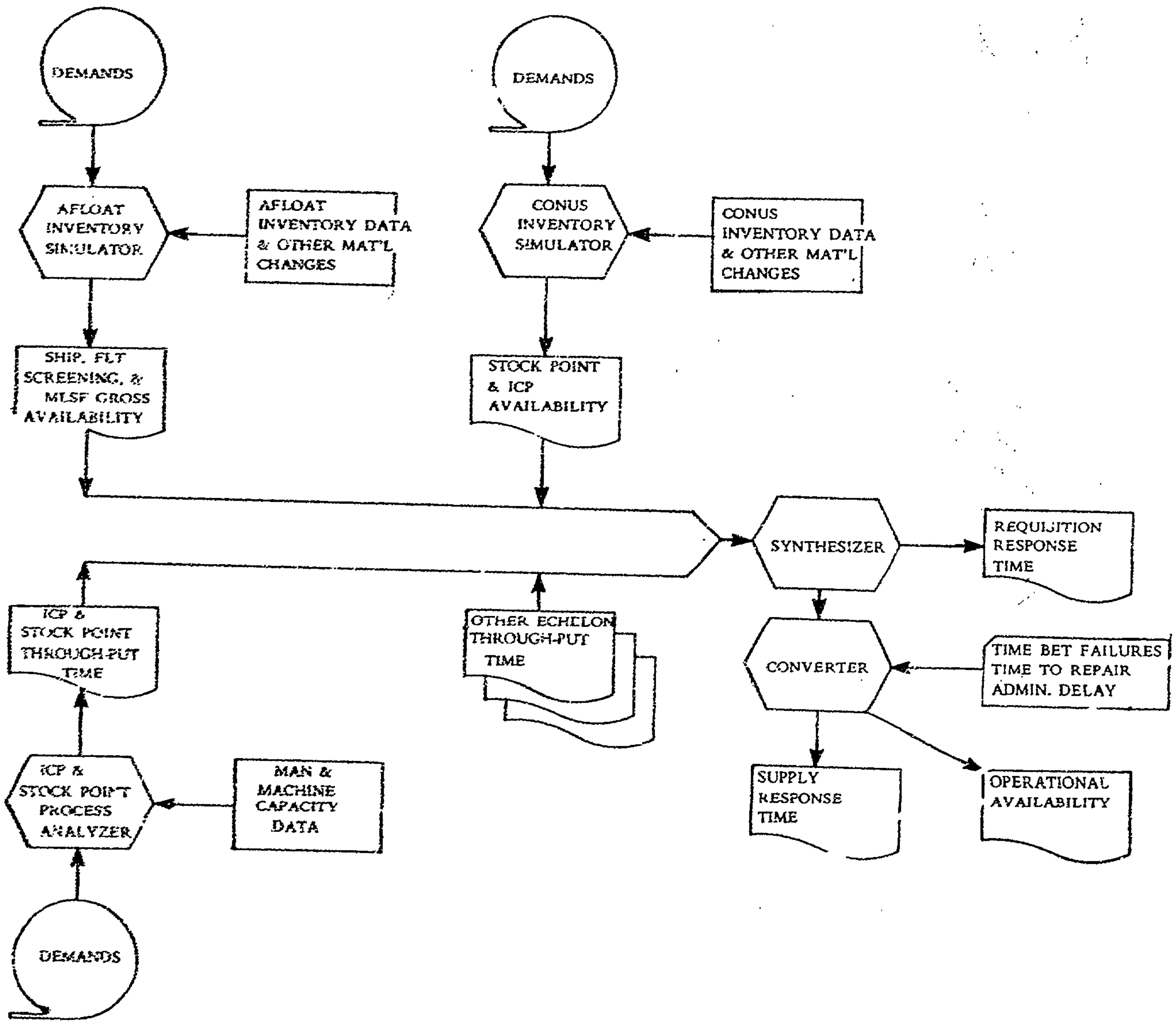


FIGURE I-2

ranging from 1 hour to 360 days. New probabilities can be computed in response to changes in workload or organizational capacity. Where the process cannot be modelled in detail for unavailability of data, existing reports can be analyzed or special studies made to deduce throughput probabilities directly.

The Synthesizer combines the outputs of the Inventory Simulators and Process Analyzers to produce estimates of (a) the distribution of requisition response time, (b) workload (issues, receipts, orders, and items carried), (c) inventory levels and (d) average, incremental, and marginal costs.

The distribution of requisition response time, transferred manually to the Converter, is used in simulating corrective maintenance actions on a particular equipment to construct an estimate of supply response time. Other necessary information, including a profile of an equipment's maintenance actions, its average time to repair and its average time between successive failures, is obtained from the 3M Data Collection System either directly or through special studies. The final output of the Converter is the operational availability, or average up-time of the equipment and the change in up-time that would result from a change in supply response time.

A detailed description of the operation of each computer program is contained in Chapter V; the mathematical basis for the programs is included in Appendix C. The assumptions on which the programs are based are discussed in Chapter IV.

Once the computer programs were built and running they were used to conduct a series of analyses and experiments to:

° Demonstrate the kinds of problems that can be illuminated with the tools developed during the study.

° Supply answers raised by potential users of the computer programs.

° Develop a basis for further detailed analyses in specific areas of supply support.

These analyses and experiments are the subject of Chapter VI.

The first analysis involved systematically changing gross supply availability and throughput time associated with each commodity at each echelon to estimate the effect on requisition response time, which currently ranges from 5 to 33 days, depending on commodity. The analysis concluded that:

° DSA managed items have the shortest response times, APA items the longest, and NSA items intermediate response times.

°There is a close inverse correlation between current response time and the improvement in response time resulting from a one percentage point increase in gross supply availability.

o Generally, a one-day improvement in througnput time at the mobile logistic support force and stock point echelons has a greater impact on response time than a one-day decrease elsewhere.

The second analysis systematically varied mean supply response time from zero to 120 days, noting the effect on equipment operational availability, given current values of mean time between failure and mean time to repair. The 38 electronic equipments analyzed were divided equally into three classes:

o Those so highly reliable that any change in mean supply response time would have virtually no effect on operational availability.

o Those so unreliable (i.e., with such a short mean time between failure) that nc reasonable reduction in mean supply response time could pull the operational availability above 50 percent.

o The remaining equipments, for which changes in mean supply response time have a noticeable effect on availability.

Seventeen specific experiments were run to predict the performance consequences of proposals made during the course of the study by various persons and groups, including an S^4 Users' Conference. For some of the experiments it was possible to estimate many of the dollar costs or savings associated with the proposal. For these and for additional proposals resulting from analysis of structural and performance data acquired during the study, the potential costs and benefits (both positive and negative) are summarized in Table I-1.

The study group does not recommend that all proposals be adopted. Some are clearly inefficient; others may be unnecessary at this time. Even many of the attractive ones should be reviewed thoroughly before adoption for these reasons:

o There may be hidden spillover effects or externalities. Additional spillovers within the realm of supply operations the study group would probably have estimated in a more extensive, time consuming analysis. The more serious externalities involving such things as ships' performance and task force operations lie beyond the competence of this study group to calculate.

o Constraints (floors and ceilings) may prevent or at least delay the adoption of an apparently worthwhile idea. Some of these are technological, political or social. Most are fiscal. Lack of funds in an O&M,N account may block execution of a proposal to save large sums of money in a material purchase account, and vice versa. On the other hand, a relatively high level of funding in an account may remove the necessary motivation to reduce total costs.

EFFECT OF PROPOSALS FOR CHANING RESPONSE TIME

REFERENCE	PROPOSAL	DOLLARS ($ 000)	RESPONSE TIME (DAYS)
Experiment 1	Remove TORs from COSAL	563 saved	0.15 increase
Experiment 4	Eliminate MATCONOFF and		
	(1) keep Norfolk availability constant	50 saved	0.45 increase
	(2) raise Norfolk availability	?	0.27 increase
Experiment 5	Close NSC Norfolk		
	(1) and send inventory to DSA	1,185 saved	0.39 increase
	(2) and eat-down inventory	10,335 saved	0.88 increase
	(3) to Sixth Fleet only	33 saved	0.88 increase
Experiment 7	Reduce wholesale range		
	(1) of 1H items	6,605 saved	2.37 increase
	(2) of 2N items	1,804 saved	22.36 increase
Experiment 8	Change wholesale stock depth		
	(1) decrease 1H	2,500 saved	1.63 increase
	(2) increase 4N	2,050 saved	0.47 increase
	(3) decrease 4N	570 saved	2.32 increase
Experiment 10	Reduce COSAL endurance to		
	(1) 60 days	553 saved	0.6 increase
	(2) 30 days	1,474 saved	1.7 increase
Experiment 11	Eliminate AFS function and		
	(1) save 1 AFS	10,700 saved	3.8 increase
	(2) save 3 AFSs	32,000 saved	3.8 increase
Experiment 19	Increase NSC Norfolk staffing 10% selectively	440 spent	.0005 decrease
Experiment 20	(1) Resupply ships by air	243 spent	?
	(2) Carry complete FILL at Norfolk	167 spent	?
Section VII D	Install AUTODIN in Sixth Fleet Ships	?	0.38 decrease
Section VII E	Computer process IPG II requisitions at Norfolk more frequently	19 spent	0.02 decrease
Section VII J	Use MAC from Norfolk	84 saved	0
Section VII J	Use MOM from Oakland	46 saved	.04 increase

TABLE I-1

The report of experiments in Chapter VI and the analyses of performance data and current doctrines in Chapter VII lead to the recommendations in Chapter VIII, which can be divided into two groups:

°Those which should produce immediate or near-term improvement in performance or reduction in cost of operating of the Navy's material support system.

° Those intended to enlarge the scope of the models developed in the current study, to imbed these models and their outputs into the Navy's planning, programming and budgeting system, and to make available to supply and operating personnel at all echelons in the Navy a logistics laboratory in which to predict the ultimate performance and cost consequences of proposed changes in the material support system.

II. PURPOSE AND SCOPE

A. Purpose

The general objective of the study, as indicated in the Study Directive, Appendix A, is to "define, develop and propose an automated model by which supply support dollar outlays may be related to fleet capability." The Study Directive specifies the study product to be a mechanism or procedure which can be used (1) to report to the CNO "the readiness of fleet units (from a supply support standpoint) and the monetary expenditures required to maintain or adjust these levels of readiness," and (2) to "justify and allocate budget dollars to supply support" in the course of the Navy's annual Planning-Programming-Budgeting System. In addition, the Study Directive indicates that the study "will result in a new OPNAV directive for the management of secondary items."

The Study Directive suggests that the elements of supply support should be broadly defined and should encompass requisite transportation and communication systems as well as those resources -- inventories, personnel, computers, and material handling equipment -- usually associated with a supply system.

The Study Directive prescribes two measures of fleet supply capability - equipment operational availability and mean supply response time. The former is the fraction of time a given equipment or weapons system is operational. One of the factors in determining operational availability is mean supply response time - the time required to requisition and assemble all the parts needed to complete a corrective maintenance action. A third measure frequently used in the study is mean requisition response time - the time required to get a single part into the mechanic's hands.

As designed, the "automated model" referred to in the study directive can be used not only for the specific purposes of readiness reporting and budget justification but can also serve as a general purpose laboratory in which a wide variety of policy proposals and procedural rules can be tested. The automated model, which consists of a series of simulators and analyzers, can, for example, answer the following questions:

- What would happen to requisition response time (or operational availability of a particular equipment) if the depth of each item in the Coordinated Shipboard Allowance List (COSAL) were cut by a specified percent?

- What would happen if the mobile logistics support force were relieved of all its end-use requisition processing functions?

o What would happen if all requisitions for material managed by the Defense Supply Agency were submitted directly from the ship to the appropriate Defense Supply Center?

o What would happen if the stock range in the COSAL were increased 25 percent?

o What would happen if the ICPs' material budgets were increased 50 percent in one year?

o What would happen if the staffs at Naval Supply Centers were permanently increased (or decreased) by 500 personnel? Would this cost more or less, in the long run, than above?

o If requisition response time were cut in half, how much would operational availability be increased?

A by-product of the study effort has been the training of a group of personnel, concentrated largely at the Fleet Material Support Office and Maintenance Support Office, in many of the details of Navy supply and transportation, particularly at the Fleet echelons. This training, combined with knowledge of operations research techniques, access to large-capacity computers and their supply data banks, and an intimate understanding of the methodology and computer programs developed in S^4, makes the group peculiarly suited to answering questions of the kind listed above and to conducting research in areas of supply system design and resource allocation.

B. Scope

The study addresses all General Purpose Forces, except Aviation. Both to simplify administrative and data collection problems and to demonstrate the feasibility of making forecasts covering a subset of the entire Navy, the locus of the study has been the Sixth Fleet and its organic and external supply support. Further to simplify data collection problems and reduce computer running time, only a sample of Atlantic Fleet ships has been analyzed; those selected are representative of the entire fleet. However, the simulators and analyzers have been designed so that with slight modification data from another Fleet or the Navy as a whole can be studied.

The supply of both NSA and APA material is analyzed in the study. However, ammunition, fuel, aviation parts and components, personnel related items and housekeeping supplies are not considered. This omission is not intended to imply that the commodities are unimportant to the support of weapons systems or the personnel who man them. However, distribution systems for ammunition, fuel, provisions, medicine, and clothing are highly specialized and have been the subject of numerous studies and investigations; another study would add little if anything to the understanding of problems associated with management of these inventories.

A description of the commodities embraced by S[4] is contained in Table II-1.

DEFINITIONS OF COGNIZANCE SYMBOLS

DESCRIPTION OF COMMODITY	COGNIZANCE SYMBOL	MANAGING ICP/DSC
Electronic Parts - NAVAIR Equip	2G	Electronics Supply Office
Electronic Parts - NAVELEX Equip	4G	
Electronic Parts - General	1N	
Electronic Parts - NAVSHIPS Equip	2N	
Electronic Parts - NAVORD Equip	4N	
Ordnance Material - General	1A	Ships Parts Control Center
Ordnance Material - NAVORD Equip	2A	
Ordnance Material - NAVAIR Equip	4A	
HM&E Parts	1H	
HM&E Components	2H	
Surface Missile Parts	2U	
Construction Material	*9C & CX	Defense Construct. SupCen
General Material, Defense	*9G & AX	Defense General SupCen
Electronic Material, Defense	*9N & TX	Defense Elec. SupCen
Industrial Material	*9Z & KZ	Defense Indust. SupCen
Part Numbered Material	PN	None

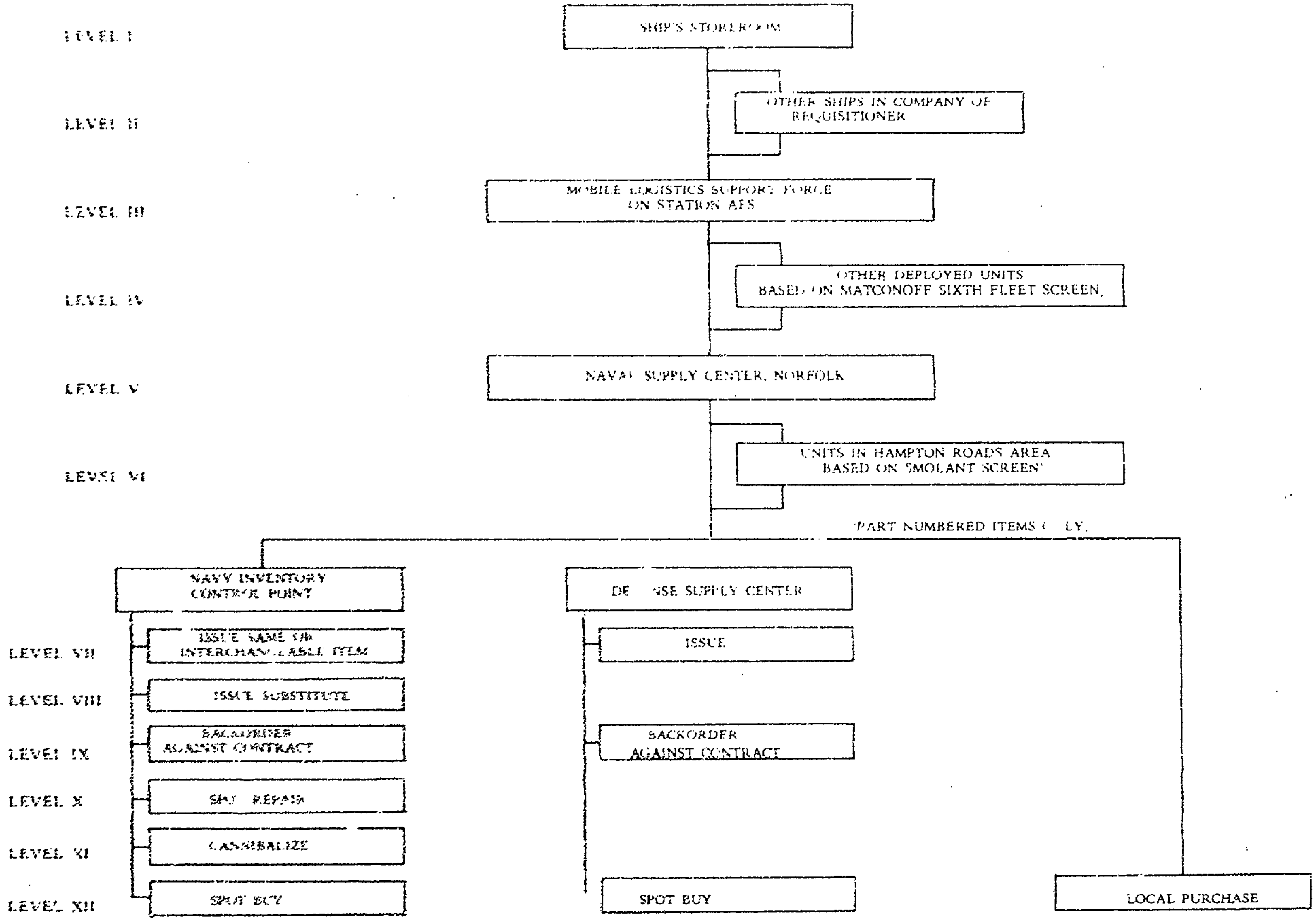
*That portion of the Inventory locally managed by NSC Norfolk is designated 9 Cog.

TABLE II-1

The study does not look at trade-offs between supply and the other factors of production that produce ready ships. Thus the effects on ship readiness of more (or less) supply vs. more redundancy vs. higher reliability and maintainability vs. more maintenance are not addressed. However, the data and conclusions produced by this study may provide useful inputs to these other trade-off studies.

Regarding personnel resources, the study considers only the effect of quantitative changes in personnel on requisitioning, purchasing, and issuing throughput times; it does not address the immediate consequences of qualitative personnel changes. For example, no tool produced in the study will forecast the increase in supply availability occasioned by hiring more capable or larger numbers of personnel. On the other hand, if supply availability improvement can be projected by another method, the techniques developed in this study will estimate the change in response time and operational availability.

SUPPLY LEVELS



III. DESCRIPTION OF MATERIAL SUPPORT SYSTEM

The simulators and analyzers built during the course of S⁴ are intended to represent the material support system of the Sixth Fleet with sufficient realism and detail to reproduce the current performance of that system with current resources and to estimate the consequences for performance of changes in resources. A first step in accomplishing these ends is an understanding of the current support system.

This chapter describes the operation of the Sixth Fleet support systems for technical material -- those commodities listed in Table II-1. For purposes of this study, the material support system is defined very broadly to include the ship's storeroom, the part or component manufacturer, and all the intervening organizations, including the necessary communication, transportation, requisition processing, materials handling, and repair-for-stock functions. The first major section describes this system structurally in terms of the organizations involved, the flow of requisitions and material, and the schedules on which requisitions and material are supposed to flow. The second section describes (where appropriate and available) the workload imposed on each element of the system, the resources available to process that workload, and the performance of each element in terms of how much material it supplies and how fast it processes or handles the material. A final section addresses overall system performance.

A. Structure

Figure III-1 portrays the major supply levels and supply sources which may be involved in satisfying a given Sixth Fleet end-use requisition. That all levels portrayed in Figure III-1 are not involved in all requisitions is due to the following:

- The requisitioning process ceases as soon as material is found; this may occur in one of the first few echelons.

- Certain echelons are employed only for CASREPT or other emergency requisitions; specifically Levels II, IV, and VI are bypassed except for emergency requisitions. Level VI is very rarely used. Level II is limited to high priority requirements which the ship's supply officer is reasonably certain can be supplied by a nearby ship. Level IV is to be employed only for requisitions related to NORS (not-operationally-ready-supply) ANORS (anticipated NORS) and CASREPT (casualty report).*

- Level III is bypassed unless the requested item appears on the AFS load list (FILL).

*COMSERVFORSIXTHFLT Msg 120804Z of April 1972

REQUISITION FLOW ABOARD USS INDEPENDENCE

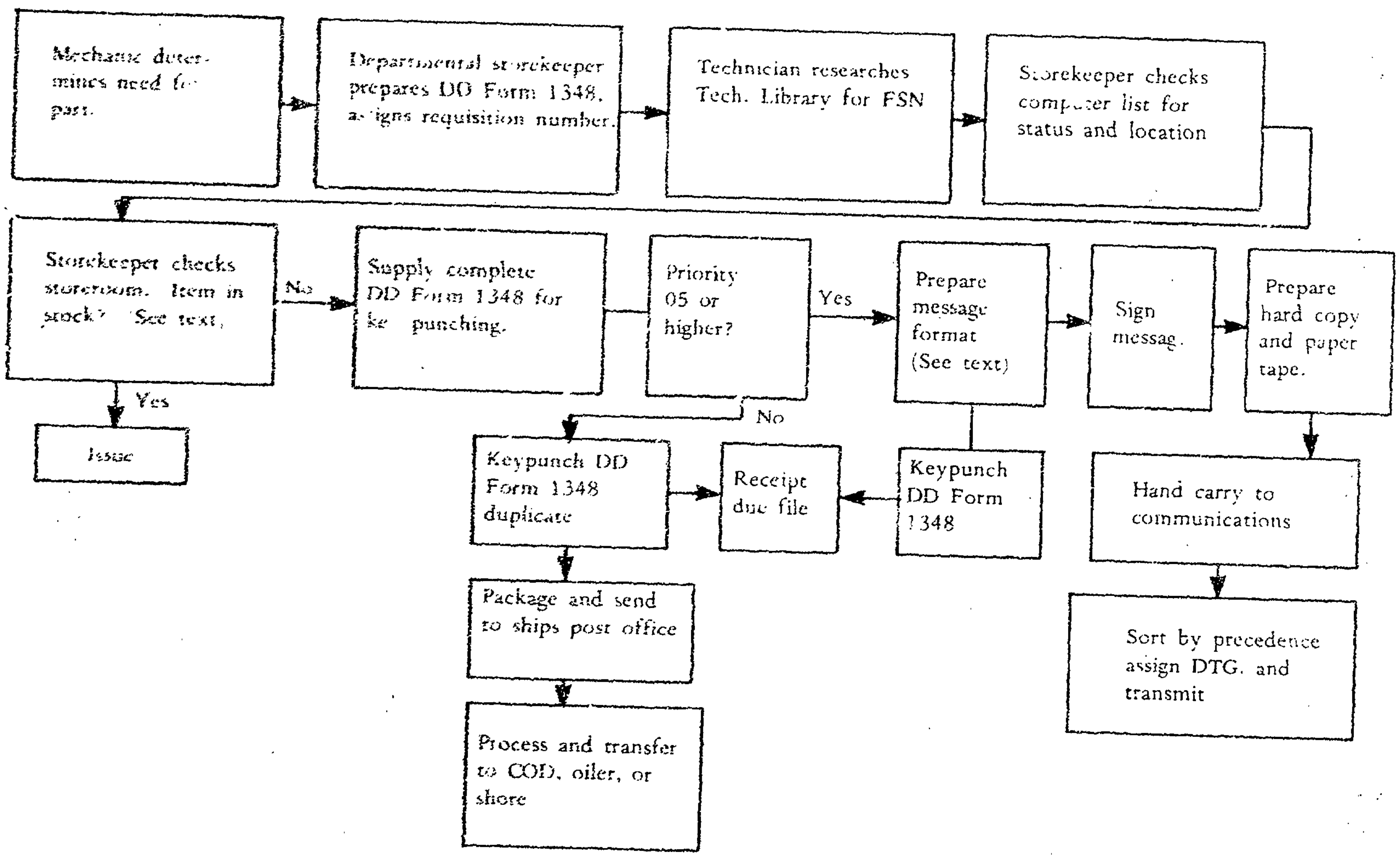


FIGURE III-2

o Some actions are mutually exclusive. Thus only one activity at Level VII through XII supplies a given item, depending on cog symbol, material control code, and absence of FSN (Federal Stock Number). Furthermore only one of the actions depicted in Levels VII through XII is executed on a given requisition.

o If the item cannot be assigned a Federal Stock Number by the ship, then the requisition skips levels II, III, IV, and VI. Its journey through other levels depends partly on NSC, Norfolk's ability either to locate a stock number or purchase locally.

o Availability in Levels VII through XII must total to unity since they represent alternative means of satisfying a given requisition. The method selected is the one which appears to provide the best combination of cost and speed of response in a particular case under current constraints.

1. Fleet Structure and Flows

The next several figures depict details of requisition flow within the responsible Fleet support organizations. Figure III-2 shows the flow of an end-use requisition from the mechanic's statement of need to the postal system or the fleet communication system. The flow is characteristic of a mechanized ship such as the aircraft carrier, USS Independence. On a ship without computer or EAM facilities available to the Supply Department a manual form of the single line item requisition (DD Form 1348) would be prepared for mail transmission; probably a paper tape would not be prepared for electrical transmission.

In rare instances, when an item is not available aboard ship, cannibalization, fabrication, or jury-rigging will be considered and employed.

The form and destination(s) of the message requisition depend on the urgency of the failure and the potential availability of stock:

o If the equipment failure involves a NORS, ANORS, or CASREPT, as prescribed in COMSERVFORSIXTHFLT message 120804Z of April 1973, the requisition will be addressed concurrently to the Naval Supply Center (NSC) Norfolk and the Sixth Fleet Material Control Officer. (In a few restricted cases, the ship can query others in compnay).

o If no emergency is involved and if the item is carried on the Atlantic Fleet's Fleet Issue Load List (FILL), the message is addressed to the Fleet Issue Ship (AFS).

o If neither of the above conditions exist or if the AFS indicates it has no stock, the requisition goes directly to NSC Norfolk.

SIXTH FLEET END-USE REQUISITION FLOW

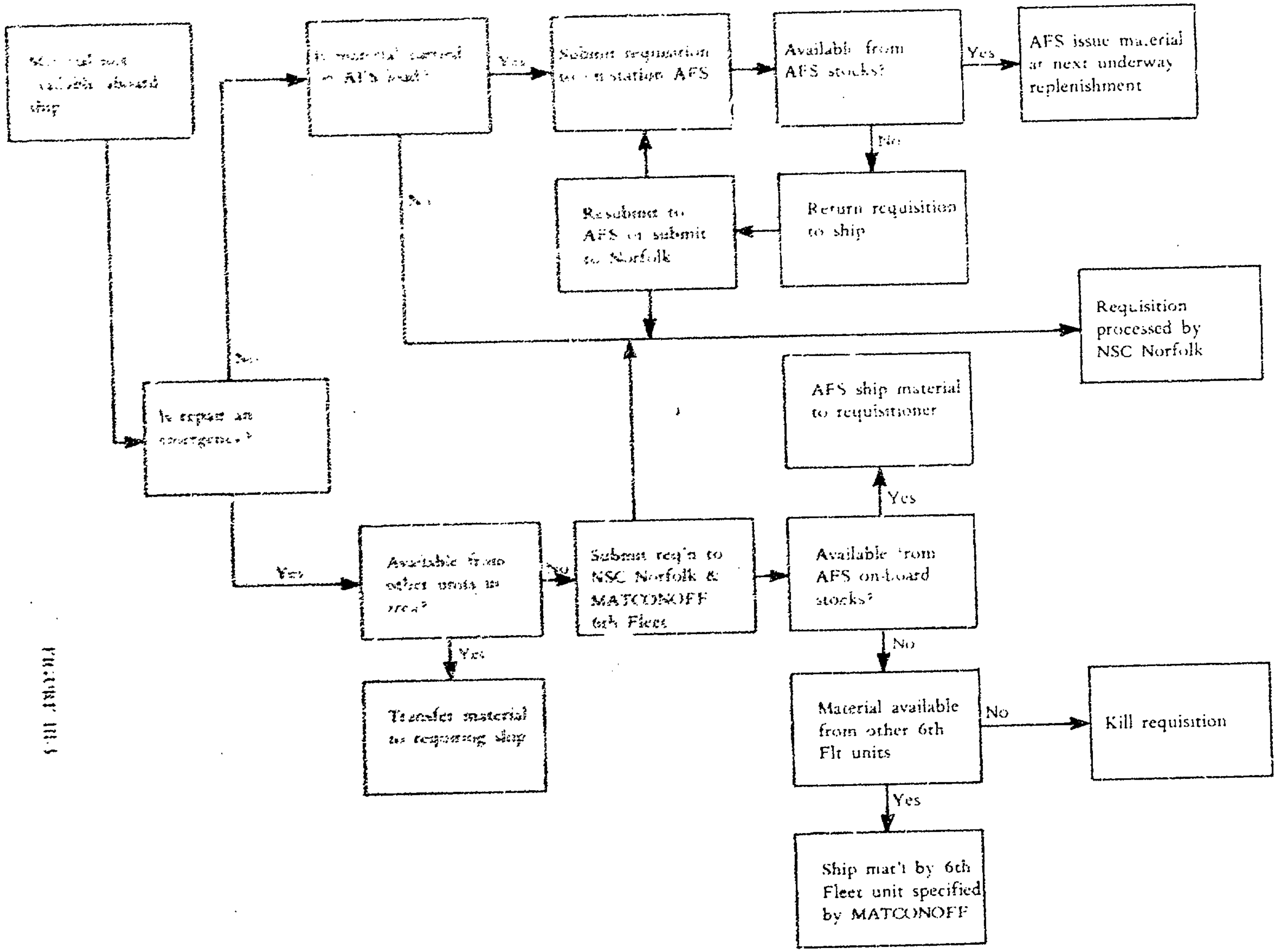


FIGURE III-3

The divergence of requisitions according to conditions is illustrated in Figure III-3, which shows the general flow of requisitions within the Sixth Fleet.

As indicated earlier, the physical transmission of requisitions is accomplished by mail or Naval message. Mail may be dropped at or flown to a Mediterranean port (preferably Rota, Spain; Naples or Rome, Italy; or Athens, Greece) where it immediately or eventually enters the U.S. Postal Service. Or mail may be transferred to another ship headed for port. Messages destined for CONUS are transmitted (a) from the requiring ship to the ship in company responsible for communication, (b) then to a transmitting station on the Mediterranean coast, (c) to a receiver at NAVCOMSTA, Norfolk, and finally (d) to the NSC communication center. Messages destined for other Sixth Fleet components are routed through communication ships.

Material flows within the Sixth Fleet are both varied and complicated. With two exceptions almost every transfer of material from one ship to another involves moving the material to the Mediterranean coast. (The two exceptions are the transfer between ships in company and from an AFS during an underway replenishment.) If neither the issuing nor receiving ship is in port, the steps in the transfer usually embrace:

- o Transfer to nearest aircraft carrier by helicopter or by coming alongside.

- o Transfer to port by COD (carrier on-board delivery) aircraft.

- o Transfer to port nearest receiving ship by truck, aircraft of the VR-24 squadron or, occasionally, of the Military Airlift Command.

- o Transfer from port to nearest carrier by COD aircraft.

- o Transfer to requiring ship by helicopter or by coming alongside.

Processing of end-use material received aboard the USS Independence is portrayed in Figure III-4.

Most requisitioning and transportation processes in the Sixth Fleet do not operate on a predetermined schedule but flow free in response to demand and available resources. For instance, requisition processing and message transmission aboard ship operate on a 24 hour basis. On the other hand, the Material Control Officer transmits status requests to all Sixth Fleet ships once a day and selects consignors from among those responding affirmatively.

As far as is known, the transportation system in the Mediterranean generally does not operate on a fixed schedule. Exceptions are (a) the AFS, which resupplies each ship once a month, (b) AOE/AORs, which resupply ammunition and fuel every three days and may transport repair parts and

MATERIAL RECEIPT ABOARD USS INDEPENDENCE

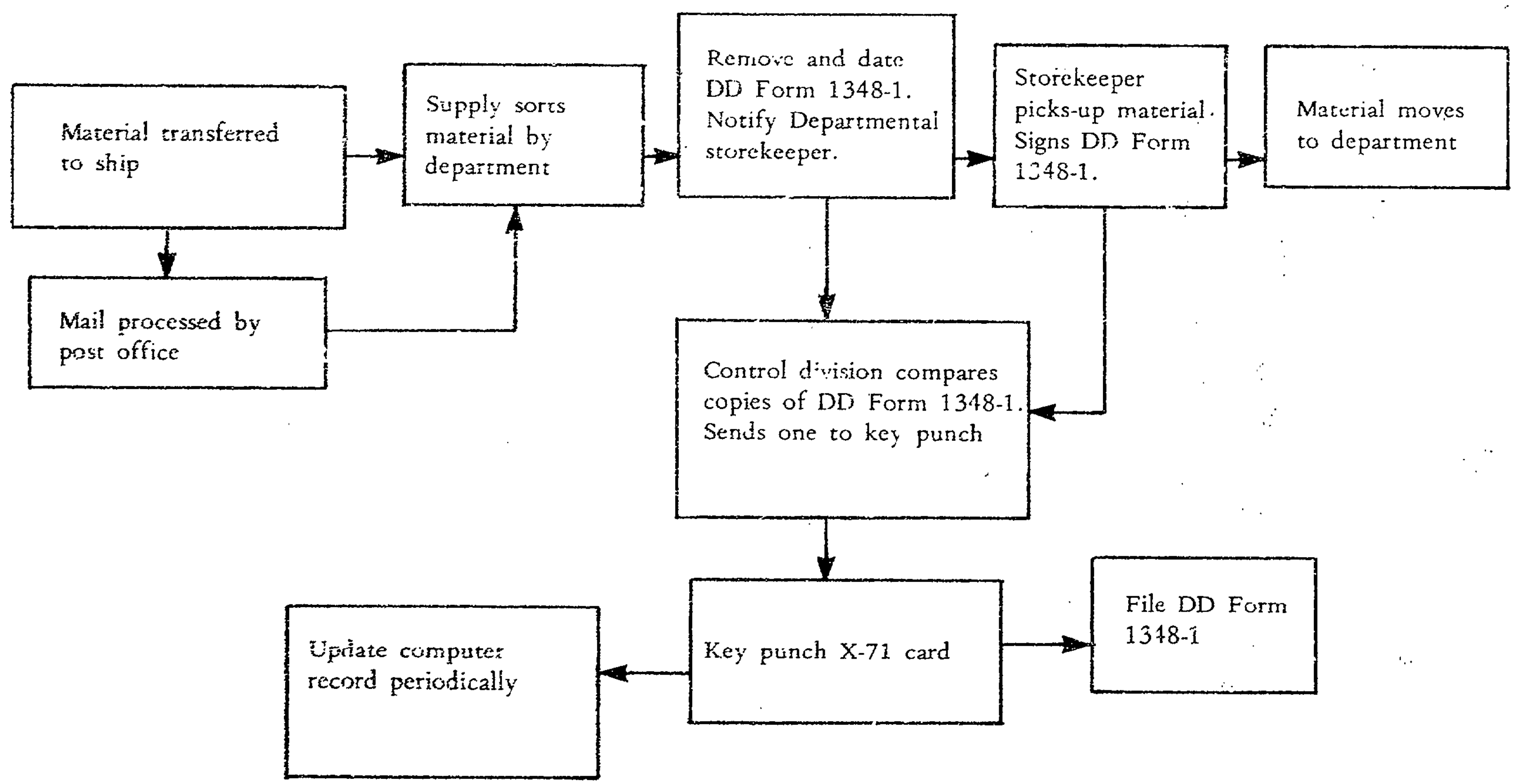


FIGURE III-4

receive retrograde cargo and (c) Military Airlift Command cargo aircraft, which complete at least a specified minimum number of flights weekly between Norfolk, Rota, Naples, and Sigonella.

Although the modelling in S^4 properly concentrates on supply of the shipboard mechanic's end-use requirement, it is obvious that supply capability would rapidly degrade if it were not for resupply of the ship's storeroom and the AFS. A complete cycle for resupply of the AFS from CONUS and the resupply of combatant ships is shown in Figure III-5.

Note in Figure III-5 that the material resupplied to using ships during the 9th to 24th day of month 3 is that which was requisitioned (a) by hard copy requisition transferred to the AFS during the replenishment in month 2 or (b) by message transmitted to the AFS in the 29 days prior to the resupply in month 3, on the day the requiring ship's stock hit its reorder point.

For items not carried or not available on the AFS, the requiring ship submits resupply requisitions directly to NSC Norfolk.

2. CONUS Structure and Flows

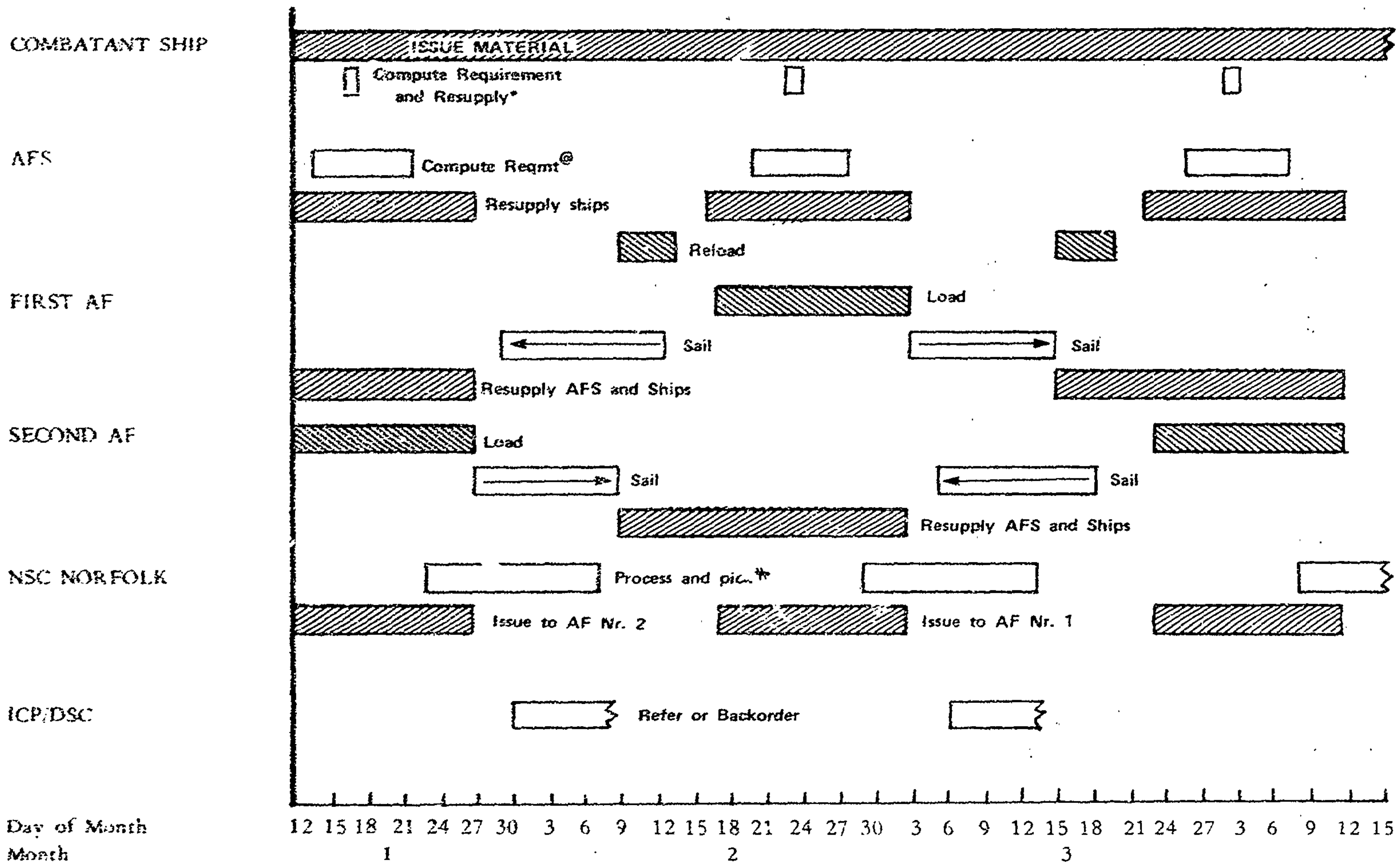
Figures III-6, III-7, and III-8 display the decision rules applied in processing requisitions at NSC Norfolk, the Electronics Supply Office (ESO) and the Ships Parts Control Center (SPCC) in terms of decision points and branches.

Processing at the Defense Supply Centers (DSC) is similar to that at ESO or SPCC, except that a DSC does not manage items subject to depot repair.

Figure III-9 contains the flow of requisitions within NSC Norfolk. The flow in an Inventory Control Point, such as ESO or SPCC, or a DSC is considerably more involved and hence not easily displayed. In general, however, stock-numbered requisitions go directly to the computer, where many are processed to the point of preparing a referral or, in the case of a DSC, a material release order, directing a stocking activity to issue.* Only if there is a shortage of ready-for-issue material or a restriction of issue is the requisition forwarded to the Stock Control Division for manual action. In the event a technical problem arises such as assignment of a stock number or determination of obsolescence or substitutibility, the requisition will be sent to the Technical Division; in the event there is no issuable stock, to the Purchase Division. Of course, non-stock-numbered items must be sent to the Technical Division for identification and then to Purchase for

*For example, 42 percent of stock-numbered requisitions received by ESO are handled completely by computer. In the case of 1N material this figure rises to 54 percent.

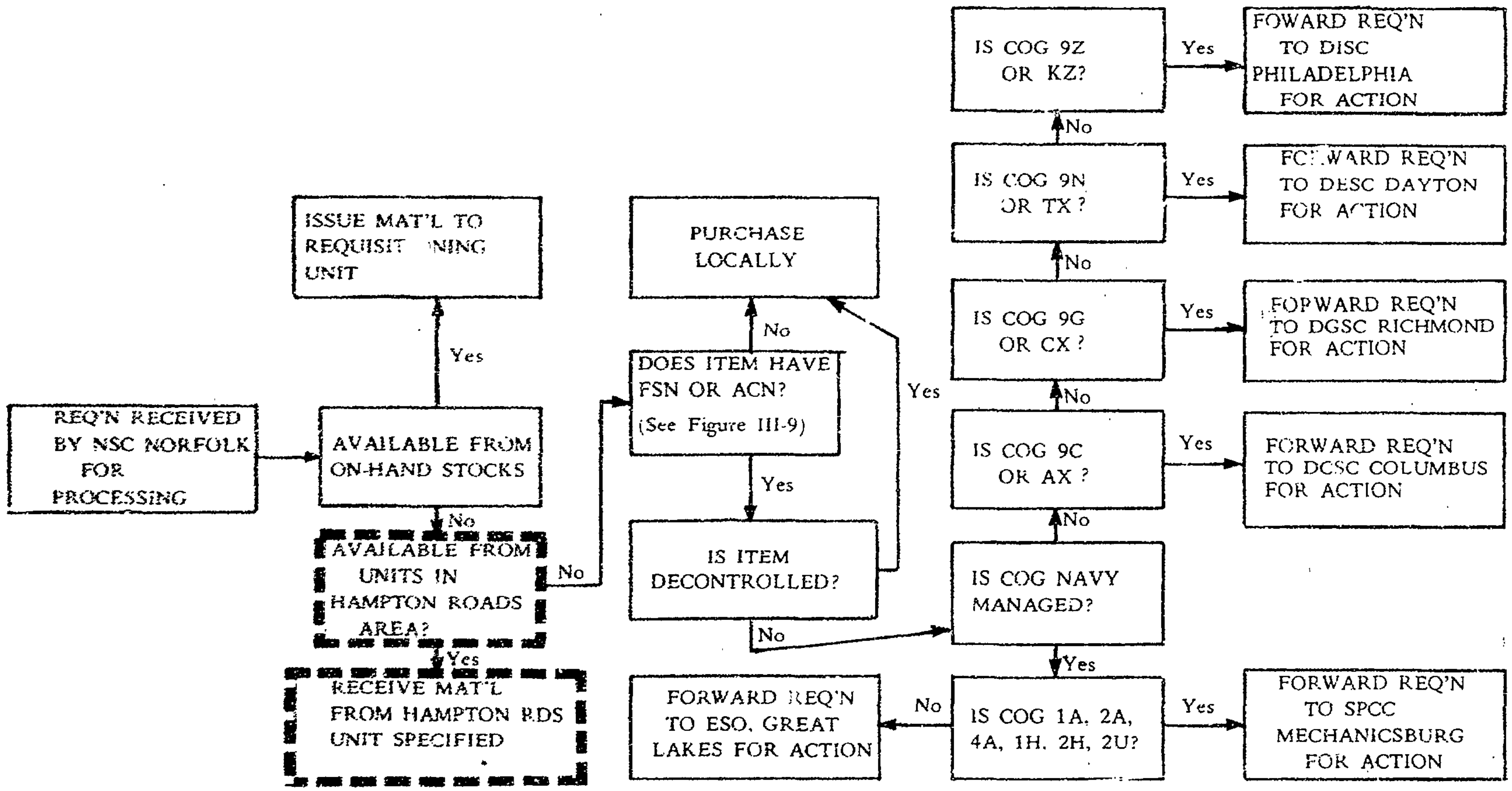
SIXTH FLEET RESUPPLY SCHEDULE



*Resupply cycle is for typical ship. For all ships, cycle extends from 9th to 24th day.
@For FILL items only. Computation cycle extends from 10th to 4th day.
#For FILL items only. Total processing runs from 15th to 10th day.

FIGURE III-5

NORFOLK DECISION RULES FOR REQUISITION PROCESSING



*Step Bypassed Except for Emergency Situations

FIGURE III-6

ESO DECISION RULES FOR REQUISITION PROCESSING

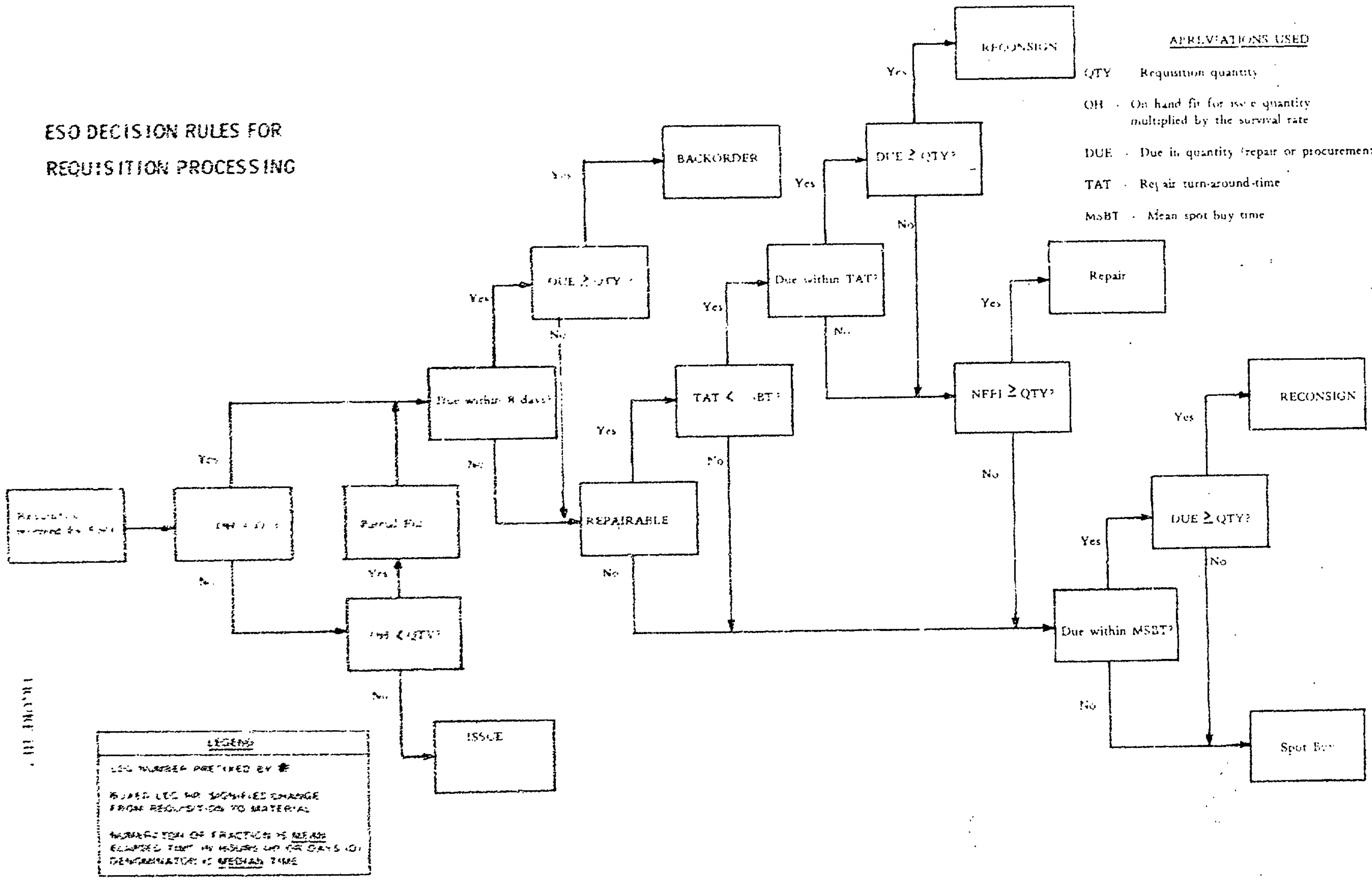
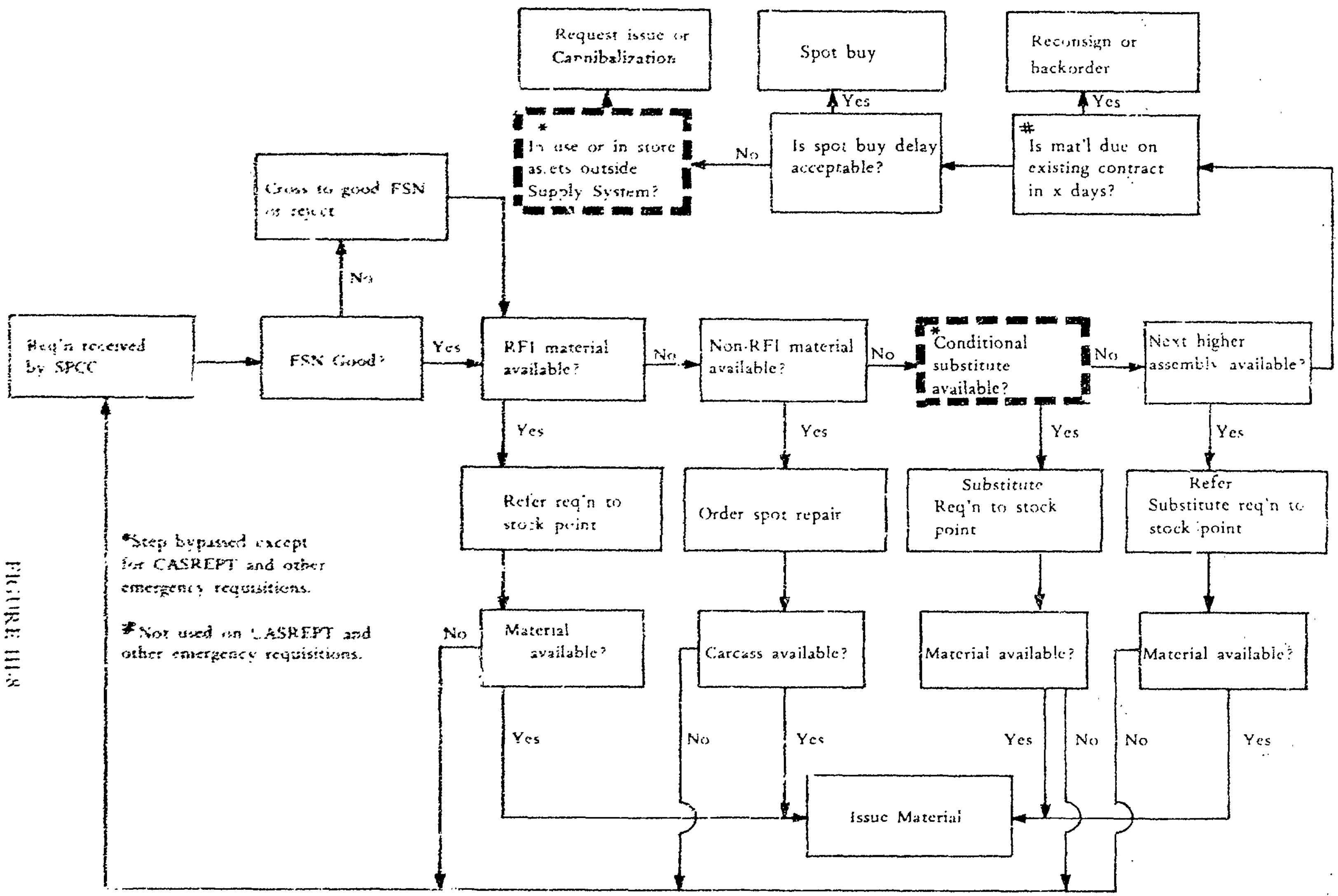


FIGURE III-

SPCC DECISION RULES FOR REQUISITION PROCESSING



*Step bypassed except for CASREPT and other emergency requisitions.

#Not used on CASREPT and other emergency requisitions.

FIGURE III-8

REQUISITION/MATERIAL FLOW WITHIN NSC NORFOLK

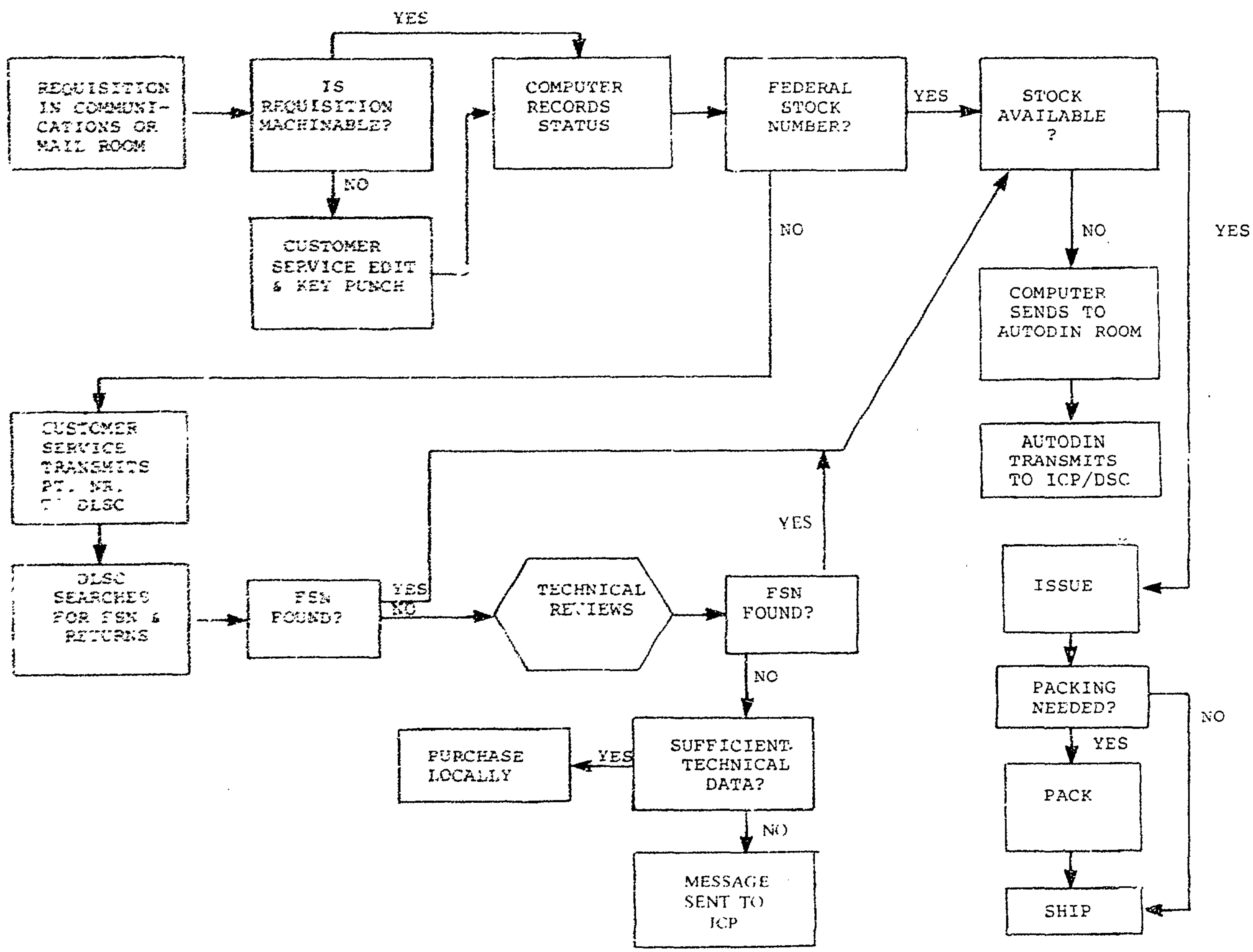


FIGURE III-9

procurement, if identification is unsuccessful.

Requisitions being processed at NSC Norfolk advance to the next processing station once an hour until they arrive at the computer. Here they are batched as indicated in Table III-1. IPG I requisitions are processed on an average every 3 hours, IPG II daily at 0500. IPG III requisitions are held in the computer until (a) the warehouse force requires more work, (b) the requisition has been in the computer one week (or for activities infrequently visited by cargo ships, two weeks) or (c) enough material has accumulated to fill a container, whichever occurs first. Beyond the daily consolidation within the computer, the only consolidation of IPG I and II requisitions occurs when several small items are consolidated into a mailable carton. IPG III material not mailable is stuffed into Seavans.

If packed material is oversized, overweight, hazardous, or for an AFS resupply, it is sent by military transport; otherwise, it is sent by mail. The IPG of the requisition determines specific carrier and service as follows:

IPG	Military Carrier	Mail Class
I	Military Airlift Command (MAC)	Air Parcel Post (APP)
II	Military Airlift Command (MAC)	Military Ardinary Mail (MOM)
III	Milita' ' Sealift Command (MSC)	Surface Parcel Post (SPP)

NSC Norfolk transfers mail at least twice daily (more often if volume warrants) to General Post Office Norfolk. It transfers material four times daily to MAC terminal, NAS Norfolk for Rota/Naples/Sigonella. Material for MSC ships is stuffed in Seavans and transferred to Norfolk International Terminal.

Mail leaving NSC Norfolk generally follows this path:

. NSC Norfolk, trucks mail to General Post Office Norfolk, where it is sorted for FPO New York or FPO San Francisco.

o FPO New York mail is trucked six days a week to the Postal Concentration Center New York where it is sorted between surface and air and by command.

AUTODIN-COMPUTER INPUT SCHEDULE

A. NSC Norfolk

1. Pickup in AUTODIN terminal room - every hour on the half hour
2. Computer Input -

HOUR	WEEK DAYS			SATURDAY & SUNDAY		
	IPG I	IPG II	IPG III	IPG I	IPG II	IPG III
0500		X			X	
0600	X			X		
0800			X			X
0900	X			X		
1000	X					
1100	X					
1200	X			X		
1300	X					
1400	X					
1530	X			X		
1830	X			X		

3. Pickup from computer room - 3 hours after entry into computer for IPG I and II; 22 hours after entry for IPG III
4. AUTODIN Transmission - within 15 - 30 minutes after computer pickup

B. NSC Oakland

Priority 1 requisitions are hand processed at once; Priority 2 and 3 requisitions are machine processed every other hour. The seven day a week mechanized processing schedule for IPG II and III requisitions is:

1. AUTODIN Pickup - 0000
2. Computer Input - 0400
3. Computer Pickup - 0830
4. AUTODIN Transmission - 0920

The computer is down between 1830 and 2030 for Planned Maintenance

C. Electronics Supply Office

1. AUTODIN Pickup - every hour on the hour between 0600 and 2400
2. Computer Input - 25 minutes later
3. Computer Pickup - 5 minutes after input
4. AUTODIN Transmission - 30 minutes after computer pickup

D. Ships Parts Control Center

1. AUTODIN Pickup (weekdays) twice per hour, on the hour & half hour
2. Computer Input - 20 minutes later
3. Computer Pickup - 5 minutes after input
4. AUTODIN Transmission - 5 minutes after computer pickup

During weekends & holidays, requisitions are processed as they arrive. Ten percent of the requisitions arrive by means other than AUTODIN. These are inputed to the computer at once. The computer is down during the second shift Thursday; the AUTODIN terminal is down 3 hours during the second shift Tuesday.

TABLE III-1

Surface mail is trucked to Army Terminal at Bayonne, New Jersey, whence it moves to Naples by ship. The entire trip (Norfolk to Naples) is said to take 30 to 45 days.

Air mail (including Air Parcel Post, Military Ordinary Mail and First Class Mail) is trucked to Kennedy International Airport for the next available flight to Madrid, Barcelona, Nice, Rome, or Athens.

From the Mediterranean aerial port of debarkation, the mail is moved to Rota or Naples by truck or train.

Material leaving Norfolk via the Military Airlift Command is flown direct to Naval installations at Rota, Naples, Sigonella, and Athens.

Regardless of how material arrives at one of the above points, it is transported to the requiring ship by COD aircraft or by ship or is held for the return of the ship to port.

In the event that NSC Norfolk cannot satisfy a demand for a Navy managed item and must refer it to ESO or SPCC, NSC Oakland is the most likely source of material. (See Table III-8.) NSC Oakland's firm policy is that IPG I and II mailable items move by air mail to FPO, New York; IPG III by surface parcel post. Non-mailable IPG I and II material is delivered to the MAC aerial port of embarkation at Norfolk via QUICKTRANS, the Navy's contract air freight system. In fact, since most Navy stock points lie along the QUICKTRANS air route or its truck extensions, effectively all IPG I and II non-mailable requisitions for the Sixth Fleet should move by QUICKTRANS or QUICKTRANS-truck combination to APOE, Norfolk.

On the other hand, if the request must be referred to a DSC for action, it may move by rail or truck to APOE Norfolk, especially if it is IPG II. This conclusion is based on two analyses: the first is a study* indicating that Defense Depot Ogden, Utah (the most likely issue point for the material under consideration) moves 30 percent of its IPG I and II issues by air parcel post and 1 percent by air freight, the second is a recent review of 20,000 issues made by Defense Supply Centers to Sixth Fleet ships, which showed that about 1/3 of the issues moved by air parcel post, 1/3 by military ordinary mail, 4 percent by air freight (including MAC) and less than 1 percent by QUICKTRANS.

The scheduling of stock status determination and referral or preparation of the DD Form 1348 is revealed in Table III-1. All Navy stock points using the Uniform Automatic Data Processing System follow basically the schedule shown for Norfolk and Oakland. Requisitions and material in all other Navy controlled operations advance to the next

*Transportation Movement Analysis by Commodity, IPG, and Mode (MOWASP F-129), May 1971; Defense Supply Agency step every hour or two, at least during the work day. Virtually all logistics communication within CONUS is conducted over AUTODIN (Automated Digital Information Network).

The Military Airlift Command is required to provide the following minimum service to the Navy:

Channel	Monthly Space Assignment	Frequency
Norfolk-Rota	300 short tons	Every other day
Norfolk-Naples	250 " "	3 flights/wk
Norfolk-Sigonella	60 " "	2 flights/wk

The QUICKTRANS system provides scheduled service six days a week from Boston to Pensacola and from Bremerton to San Diego as well as cross-country service via Indianapolia and via the southern United States.

Although each individual segment of the Postal Service operates on a fixed schedule, there is no overall schedule governing delivery from CONUS points to Rota, Naples, and Athens. Nevertheless a reasonable schedule for air parcel post might look something like this:

Mail leaves NSC Norfolk or Oakland	1700 Day 1
Mail leaves San Francisco airport	2400 Day 1
Mail leaves General Post Office, Norfolk	2200 Day 1
Mail arrives Postal Concentration Center (PCC) Brooklyn from Norfolk	0700 Day 2
Mail arrives Air Mail Facility (AMF), Kennedy Airport from San Francisco	0800 Day 2
Mail arrives AMF from PCC	1500 Day 2
Mail leaves Kennedy International Airport	1800 Day 2
Mail arrives Madrid Airport	0400 Day 3
Mail arrives NAS Rota	1800 Day 3
Mail arrives Rome Airport	0600 Day 3
Mail arrives Naval Station Naples	1400 Day 3

The above schedule would also be applicable to military ordinary mail (MOM) and First Class parcel mail from Norfolk since all classes are trucked to the PCC. On the other hand, at least 4 days must be added for surface transportation of MOM from the West Coast.

B. Workload, Resources, and Performance

The processing of requisitions and movement of material described in Section III A must, of course, be conducted by specific activities and companies. The collective performance of these organizations will determine how well (specifically, how fast) the processing of requisitions and material occurs. Individual agency performance, in turn, is a function of the workload imposed on the agency and the resources at its disposal. Quantitative description of the performance, resources, and workload of each stocking echelon and each communication, transportation and processing activity is the subject of this section. Where appropriate, the costs (such as salaries or tariffs) an activity must pay for services are included.

Performance is the output of a system as seen from the viewpoint to the system's customers. Workload, often employed as an indicator of performance, is a poor measure because, somehow, all the work loaded onto a system is eventually finished. The customer assesses performance not on what was done but on the manner in which it was done, the accuracy and quality with which it was done, and the speed of accomplishment.

In S^4 two measures of performance are attached to each supply echelon holding stock -- its gross supply availability and its throughput time. Gross supply availability is the number of requisitions satisfied from stock divided by the number of requisitions received by an echelon and is intended to represent the echelon's ability to satisfy demands relatively quickly from available inventory. The "echelon" may consist of a single point, such as NSC Norfolk, or the entire wholesale echelon of stock managed by an ICP or DSC. Throughput time for an echelon is the length of time elapsing from a mechanic's request for material until the material is made available to him from the echelon. This section will generally not contain throughput-time data but will instead indicate processing times for selected steps in requisition communication and processing and material handling and movement. Processing time is the calendar time required for a requisition or material to complete a leg on its journey from mechanic to supplier to mechanic.

1. Sixth Fleet Ships

Table III-2 contains the COSAL (Coordinated Ships Allowance List) inventory for selected ships as of June 1971. The ships listed are those included in the S^4 Fleet Simulator, to be described in Chapter V. The table also shows the total number of demands placed on each ship's storeroom annually for the commodities investigated in S^4 and the range of

SAMPLE SHIP INVENTORY, DEMAND AND AVAILABILITY

HULL NUMBER	INVENTORY IN DOLLARS[1]	DEMANDS ON STOREROOM[2]	GROSS SUPPLY[3] AVAILABILITY
DD 692	$ 415,355	2858	49-60%
DD 709	276,984	2348	42-69%
DD 715	261,598	2503	44-82%
DD 822	219,074	2133	41-66%
DD 862	313,976	2653	38-60%
DD 933	305,473	2608	42-67%
DDG 10	723,556	5111	53-77%
DDG 35	881,343	6014	55-71%
DE 1021	165,298	1848	11-55%
DLG 16	1,133,004	5660	61-76%
DEG 4	719,882	2284	8-65%
CG 10	2,025,745	8689	57-75%
CLG 7	687,703	9849	50-73%
CVA 62	N/A	1525	N/A
CVA 67	N/A	2572	N/A
AE 17	173,492	858	21-69%
AO 109	152,332	895	40-69%
AO 147	250,242	1072	21-65%
AOE 3	N/A	2100	53-75%
AOR 2	348,834	1846	58-90%
LKA 117	347,336	1137	49-88%
LPA 249	370,484	2738	39-82%
LPD 4	273,601	2554	49-87%
LSD 25	145,091	1289	36-71%
LST 1175	142,909	884	24-81%
PG 93	66,413	262	55-100%
SS 416	324,969	569	18-29%
SSN 607	1,195,638	860	20-100%

1. As of June 1971. Source: ACCESS, Report 7

2. As of June 1971. Source: 3-M Data

3. Minimum and maximum monthly values for the period January 1970 through May 1971. Source: ACCESS, Report 7: Includes all demands, not just those reported as relating to specific equipment.

TABLE III-2

gross supply availabilities for the ships.

The following marginal costs have been estimated by discussions with knowledgeable shipboard personnel:

- Cost to replenish stock (including receipt): $1.36 for mechanized ship, $2.10 for others.

- Cost to requisition for direct turnover (including receipt): $0.96 for mechanized ship, $1.70 for others.

- Cost to issue per line item issued: $1.01 for mechanized ship, $1.29 for others.

- Inventory holding cost: 12.5% per annum of value of material held.

These cost figures to do not imply that, for example, the annual accounting costs assigned to the ship will rise by $1.01 if one additional demand is placed on the storeroom annually. In reality what happens as demands increase is that either (a) personnel work harder or longer hours or (b) the time to complete an issue increases. This situation continues until personnel capacity reaches a limit or until service degrades to an intolerable level. At this point, additional personnel must be hired. Their salaries (including fringe benefits) averaged over the additional workload should yield the unit marginal cost figures cited above.

Virtually no recorded data are available on the total time (from mechanic's request to issue of material to mechanic) needed for a ship in the Sixth Fleet to respond to an end-use demand. Based on responses from fleet personnel (COMSERVRON SIX Msg 031544Z of December 1971) and from individuals familiar with fleet supply operations it is estimated that from 2 hours to 1 day are required to issue material aboard ship and that 2 days are required to acquire material from a ship in company.

Communication times for IPG I and II requisitions from Sixth Fleet ships to NSC Norfolk are as follows:

	Message	Mail
From requisition preparation to transmission	31 hrs.	
From transmission to receipt, NSC Norfolk	13 hrs.	
Total	44 hrs.	8.4 days
Percent going by each mode	53%	47%

2. Fleet Issue Ship (AFS)

The sales from the Sixth Fleet AFS totalled $1,967,300 during

FY 1971 from an average inventory of $1,476,000. The gross demands that could have been placed on the AFS and the number actually satisfied are displayed in Table III-3. In practice, combatant ships do not place demands on the AFS for items not included in the Fleet Issue Load List. On the average, the AFS satisfied about 95 percent of the demands directed to it.

ANNUAL DEMANDS ON AFS

COG SYMBOL	POTENTIAL REQUISITIONS PLACED	ACTUAL REQUISITIONS SATISFIED
1A	975	206
1H	7129	4161
1N	5348	2809
2A	245	42
2G	65	0
2H	333	94
2U	80	0
4A	3	0
4G	771	473
4N	611	163
9C	10314	5421
9G	13273	8900
9N	26737	16990
9Z	19325	11991

TABLE III-3

3. Material Control Officer (MATCONOFF) Screening

The third, or screening, echelon does not have an inventory of its own but, operating from the AFS currently in the Mediterranean, attempts to satisfy extremely urgent shipboard requirements by querying other ships in the Sixth Fleet. Its success in satisfying these urgent requirements is about 60 percent, with 2/3 of the available material coming from the AFS itself, the remainder from all other Sixth Fleet ships.

The total time required to satisfy a requisition by this method is 8 days, if the material comes from the AFS, and 12 days otherwise. (A routine end-use request on the AFS is filled in a time equal to one-half the ship's replenishment frequency, or 15.5 days.)

The MATCONOFF operation aboard the AFS requires the full time services of 3 storekeepers and 4 communicators. The annual direct cost for this operation is about $50,000. This amounts to $8.68 per request handled or about $14.50 per request satisfied through screening.

4. NSC Norfolk

Pertinent statistics about the operation at NSC Norfolk during FY 1972 are presented in Table III-4. Total requisitions are composed of (a) point-of-entry (POE) requisitions submitted by customers either directly or through a subordinate supply echelon and (b) requisitions referred by an ICP or DSC in the almost certain knowledge that Norfolk will be able to issue.

Relevant average costs at Norfolk are:

Cost to make an issue: \$1.17 per line item issued

Cost to manage an item: \$0.79 per year

Cost to receive material: \$6.72 per receipt

Cost to replenish locally: \$7.68 per purchase

Inventory holding cost: 13.5% of value of material held

For the most part, these estimates were obtained by correlation of monthly production and cost data appearing in NAVCOMPT Form 2168.

Resources at an activity can be measured in terms of machines and personnel or in terms of their capacity to perform work. Ideally capacity figures should be based on engineered time standards. However, these standards are generally not available at NSC Norfolk or the ICPs. Therefore, the following alternative method was developed:

Compute the rate of output (units produced divided by man-hours used) for each of several observations of production (say, 12 months' worth)

Select the highest of these rates for each function and multiply it by the largest number of personnel assigned to the function in the time periods observed. The product is at least a lower bound on the maximum capacity of the organization.

By the method just described, the capacities, expressed in requisitions per hour, of selected functions at NSC Norfolk are:

Purchase Division	34 reqn./hr.
Technical Division	54 reqn./hr.
Customer Service	1578 reqn./hr.
Issue	1770 reqn./hr.
Packing	1235 reqn./hr.
Computer	Practically unlimited

NSC NORFOLK REQUISITION AND INVENTORY STATISTICS

COG SYM	TOTAL REQUISITIONS	TOTAL ISSUES	POE** REQUISITIONS	POE AVAILABILITY	DEMAND VALUE ($000)(FY1972)	INVENTORY VALUE ($000)(END FY72)
1A	80,130	66,608	37,716	61.0%	2,305	19,796
1H	183,657	140,945	106,890	60.0	11,064	43,001
1N	177,983	146,330	100,239	68.4	7,415	30,070
2A	12,211	10,044	4,728	34.2	4,987	30,993
2G	1,738	1,611	255	43.6	1,774	4,072
2H	17,579	14,329	6,481	49.9	13,621	40,096
2N	10,926	9,278	3,296	50.4	8,974	13,578
2U	533	408	205	39.0	184	1,370
4A	25	24	5	80.1	313	1,606
4G	13,864	10,571	6,037	45.5	6,479	11,963
4N	8,467	6,506	3,717	47.2	6,108	16,403
9C(AX)*	404,030	295,097	197,665	44.9	11,924	16,725
9G(CX)*	294,854	238,719	158,208	64.5	16,344	15,963
9N(TX)*	873,886	686,051	440,286	57.3	12,338	28,066
9Z(KZ)*	617,923	512,632	313,905	66.5	10,383	12,713

* Includes DSA material managed both by NSC Norfolk and by DSCs.

**Point-of-Entry

TABLE III-4

5. Inventory Control Points and Defense Supply Centers

Essential workload, inventory and performance statistics concerning inventory manager operations are presented in Table III-5. Note that neither the ICPs nor the DSCs must process all requisitions shown in the first column of figures. In the case of the ICPs roughly 50 percent of these are completely handled at a Navy stock point and appear at the ICP only as a report of a completed transaction. (For DSCs the percentage handled locally is significantly lower.) Conversely, requisition processing and spot-buying by no means constitute the entire workload at an ICP or DSC.

The three percentage figures for the wholesale system should total to approximately 100 percent, since immediate issue (or referral), delayed issue (or backorder) and spot-buy (or direct vendor delivery) are the three main methods of requisition satisfaction at the wholesale echelon. (Substitutions are usually included in immediate issues, spot repairs in delayed issues.)

Selected average unit costs assocaited with an ICP or the wholesale echelon as a whole are:

	ESO	SPCC
Cost to manage an item per annum	$ 9.60	$16.50
Cost to place an order under $2500	44.00	37.00
Cost to place an order over $2500	82.00	75.00

Capacities to perform selected functions within ESO are (in requisitions per month):

Stock Control processing	19,125
Technical Division review	5,243
Purchasing	2,500
Data Processing (manual)	48,439

Capacities of various requisition processing functions at SPCC are (in requisitions per month):

Selected item purchase	17,976	Strategic systems	10,214
Buying operations	4,484	Special support	4,687
Contract management	7,156	Requisition control	51,156
Technical assistance		Stock control	
Ordnance	6,216	Electrical & Hardware	25,536
HM&E	14,162	Machinery & Equipment	15,237
Nuclear weapons	559	Weapons	21,873
Nuclear propulsion	2,540	Nuclear propulsion	386
Material management	5,174		

Neither cost nor capacity figures have been collected on the Defense Supply Centers.

ICP-DSC WORKLOAD, INVENTORY AND PERFORMANCE STATISTICS

COG SYM	ICP/ DSC	TOTAL REQUISITIONS [1]	SPOT BUYS [1]	DOLLAR DEMANDS (In Millions) [2]	ON HAND INVENTORY (In Million $) [3]	PERCENT SATISFIED BY System Issues Immed.	System Issues Delayed	Spot Buys
1A	SPCC	207,715	10,061	$ 19.4	$ 92.4	88.4%	7.7%	4.8%
1H	SPCC	442,456	50,631	88.2	214.5	85.7	8.6	9.8
1N	ESO	449,307	13,115	29.3	99.0	86.7	11.4	2.9
2A	SPCC	37,438	1,340	40.9	135.7	82.2	14.9	3.6
2G	ESO	6,236	758	10.3	11.5	64.7	23.2	12.2
2H	SPCC	47,866	5,098	70.3	181.5	71.7	18.7	10.7
2N	ESO	27,464	1,061	28.3	31.2	67.1	28.7	3.9
2U	SPCC	4,822	235	19.9	15.2	85.3	9.8	4.9
4A	SPCC	1,461	21	4.7	13.4	94.7	3.9	1.4
4G	ESO	46,825	1,447	23 8	27.0	75.6	21.5	3.1
4N	ESO	22,443	514	24.4	54.6	75.8	22.1	2.3
AX	DCSC	3,314,141	338,375	N/A	N/A	84.3	8.7	7.0
CX	DGSC	2,248,560	394,442	N/A	N/A	84.7	9.9	5.4
TX	DESC	5,208,356	74,744	N/A	N/A	90.9	7.9	1.2
KZ	DISC	5,627,346	117,998	N/A	N/A	93.9	4.8	1.3

1. FY 72 Total
2. FY 71 Total
3. As of 30 June 1971

TABLE III-5

ICP/DSC AVERAGE PROCESSING TIMES

COG SYM	BACKORDER TIME Spec. Study	MILSTEP	Adm.Time	Prod.Time	Tot.Time	MILSTEP SPOT BUY
1A	110	121 da	---	---	114 da	125 da
1H	88	87	---	---	114	86
1N	112	97	104	84	188	126
2A	98	95	---	---	114	226
2G	51	94	32	33	65	82
2H	142	92	---	---	114	209
2U	65	45	---	---	114	91
2N	142	161	126	101	227	169
4A	---	47	---	---	114	95
4G	117	160	139	116	255	187
4N	149	96	95	97	192	147
AX	59	113	---	---	118	114
CX	46	76	---	---	37	40
TX	47	55	---	---	141	78
KZ	51	63	---	---	N/A	81
Part Numbered Items		(Norfolk)	15	30	45	---
		(ESO)	39	65	104	---
		(SPCC)	57	70	127	---

TABLE III-6

Table III-6 provides estimates by two different methods of the time an item remains on backorder at an ICP or DSC and is in a spot-buy status at an ICP, DSC, or (in the case of part number purchases) at NSC, Norfolk. One method (labelled MILSTEP) is to divide the number of outstanding backorders (or spot-buys) reported in MILSTEP or its feeder reports for FY 1972 by the number established during the month. The quotient is the average time on backorder (or spot buy) expressed in months. The other values are taken from various analyses:

- 2,380 IPG I & II backorders released at SPCC in October 1972
- 52,500 spot buys at SPCC
- 12,270 backorders released at ESO in July, August, and September 1972
- 5,820 spot buys at ESO in July, August and September 1972
- All Navy referrals, backorders, and spot buys handled by four DSCs in October - December 1973
- Part-numbered items purchased at Norfolk and reported in Economic Analysis of Processing non-FSN Requisitions in the Navy Supply System; LCDR G. N. Kachigian; November 1970; Naval Supply Systems Command.

As a general rule, inventory control points allow a vendor 15 days to submit a quotation on an IPG I requisition, 30 days on an IPG II. NSC Norfolk, receives telephonic quotations upon initial solicitation in some cases and allows a week for quotation in other cases.

6. Airlift Agencies

The Military Airlift Command (MAC), a command of the U.S. Air Force, provides airlift services to the four military organizations primarily from CONUS to overseas aerial parts.

COST AND SCHEDULE STATISTICS

MILITARY AIRLIFT COMMAND

	NORFOLK (NGU) TO ROTA (RTA)	NORFOLK TO NAPLES (NAP)	NORFOLK TO SIGONELLA (SIZ)
Hours between flights[1]	25.09	31.54	71.225
Transit time in hours[2]	7 hrs. 25 min.	28 hrs. 27 min.	29 hrs. 55 min.
Maximum flights/day[1]	3	3	2
Maximum days between[1] flights	2	2	6
Cost (Dollars per cwt)[3]	$21.10	$23.90	$25.30
Percent Sixth Fleet cargo dropped[4]	9.39	30.61	0

[1] NMTO, Oakland, "Major Eastbound Channel Airlift Summary" for June, July, and August 1972.
[2] MAC Cargo Schedule, 21st Air Force, October 1972. Includes layover time.
[3] AFR 76-11 of 25 September 1972.
[4] Air Terminal Cargo Movement Report.

TABLE III-7

In FY 1972, MAC lifted 619,000 tons of cargo an average of 7500 miles between 86 terminals throughout the world. To accomplish this, it used 257 Starlifters (C-141) and 48 Galaxys (C-5) operated by MAC plus some commercial augmentation. Of the 517,000 tons moved through established channels, 50 percent was Air Force cargo; 18 percent Navy cargo.

MAC does not release load-factor information by channel or for the system as a whole. However, it is generally conceded that the Norfolk-Mediterranean channels have the highest load factors and that the Norfolk APOE (NAS, Norfolk) has one of the shortest port delay times within CONUS. Selected information on these channels is contained in Table III-7.

The Navy's continental contract airfreight system, called QUICKTRANS,

COST AND SCHEDULE STATISTICS

QUICKTRANS

ORIGIN AREA	ORIGIN PORTS	COST PER HUNDRED WEIGHT	SELECTED ORIGIN STOCK POINTS	PROBABILITY OF SHIPMENT OF TECHNICAL ITEM	AVERAGE FLIGHT TIME	TIME BETWEEN FLIGHTS
NORTHEAST	BOSTON NSY # QUONSET NAS McGUIRE AFB # PHILA. NSY # WILMINGTON WASHINGTON # PATUXENT NAS DOVER AFB #	$ 5.87	NSY, BOSTON NSC, NEWPORT NSY, PROTSMOUTH* NSY, PHILA.*	0.1653	4.25 hrs.	33.6 hrs.
SOUTHEAST	CHERRY PT MCAS # CHARLESTON AFB ALBANY NAS # JACKSONVILLE NAS PATRICK AFB MCDILL AFB # KEY WEST NAS PENSACOLA	$ 4.34 $12.54	NSC, CHARLESTON NAS, PENSACOLA* NAS, JACKSONVILLE* MCAS, CHERRY PT.*	0.1584	6.25 hrs.	24 hrs.
SOUTHWEST	SAN DIEGO NSC LONG BEACH NSC # PT. MUGU LEMORE NAS	$33.55	NSC, SAN DIEGO NSC, LONG BEACH	0.2149	12.83 hrs.	28.0 hrs.
ALAMEDA	ALAMEDA NAS TRAVIS AFB #	$31.25	NSC, OAKLAND	0.3632	8.5 direct 18 hrs via SW,SE	28.0 hrs.
NORTHWEST	WHIDBEY I. NAS # BREMERTON NSY # McCHORD AFB # PAINE FIELD	$39.84	NAS, ALAMEDA* NSC, PUGET SOUND	0.0982	14.75 hrs.	33.6 hrs.

Truck terminal only

*Included in probability of shipment only when volume of issues in commodities in S^4 is significant.

TABLE III-8

is actually composed of three subsystems: an airlift operation, a cargo handling operations at terminals and 15 commercial truck transport routes to feed cargo over short, low volume runs into the airlift system. Cost and schedule information is summarized in Table III-8.

The QUICKTRANS system now has a mixture of Hercules and Electra aircraft, but is expected to operate in FY 1974 with four Hercules (L-100-30). This will force a slight reduction in flight frequency from that shown in Table III-8.

It is expected that in FY 1974 QUICKTRANS will fly 3,900,000 miles and lift 48,000 tons of Navy cargo from 30 terminals (including truck terminals), 15 of which are operated by the QUICKTRANS service. Anticipated load factor is 76 percent.

7. U.S. Postal Service

The U.S. Postal Service has three classes of overseas parcel mail service to the Department of Defense involving air delivery. The most expensive, and presumably fastest, class is air parcel post (APP). It moves by air or equally expeditious means within the continental United States and by commercial air to the overseas destination. First class parcel mail also moves by air during its entire journey, except that on its overseas leg it is classified as MOM -- military ordinary mail. Military ordinary mail ranks "with but after" APP, riding in the same aircraft except in the unusual case when "orange-bag" mail (APP) fills all available cargo space. Mail endorsed "MOM" at point of origin supposedly travels by surface within CONUS and with MOM priority overseas.

The U.S. Postal Service charges the military services a sliding rate per pound for movement within CONUS regardless of distance moved. The overseas rate via air from Kennedy International Airport to Rome, Italy, is 69.27 cents per pound for APP, 46.93 cents for MOM. The total price charged for various poundages is shown in Table III-9. Because values displayed are at the rate break points, the figures really indicate minimum costs. For example, a 15 pound package package moving via APP from Norfolk would cost $22.39.

For comparison purposes, MAC and MAC-QUICKTRANS costs for the same weight packages are shown. The costs are the sum of the rates in Tables III-7 and III-8 to which has been added a TCMD (Transportation Control Movement Document) preparation cost of $2.44. This value, estimated by NSC Norfolk, includes $0.74 in clerical cost and $1.70 in warehousing cost. With respect to the QUICKTRANS portion of these costs, it can be argued that the annual QUICKTRANS contract is fixed cost to the U.S. Navy and therefore really should not be considered in making decisions about how to move material from, say, NSC Oakland to the Sixth Fleet. By the same token MAC operating costs are a fixed value in the eyes of the Department of Defense, as are the costs of operating the Postal Service as the Federal Government sees them.

TRANSIT TIMES AND COSTS TO SIXTH FLEET

Via Mail and Military Air Carrier from NSC through Fleet Mail Center, Naples

WEIGHT IN LBS	MODE OF SHIPMENT			
	APP	1st Class	MOM	MAC-QT
		Cost from NSC Norfolk		
1	$ 4.69	$ 4.47	$ 1.97	$ 2.68
14	13.70	10.97	8.07	5.79
27	30.70	24.67	15.67	8.89
40	46.20	37.27	23.02	12.00
70	79.48	63.85	39.35	19.17
		Time from NSC Norfolk		
All	6.60 da.		7.05 da.	6.99 da.
		Cost from NSC Oakland		
1	$ 4.69	$ 4.47	$ 1.97	$ 3.01
14	13.70	10.97	8.07	10.46
27	30.70	24.67	15.67	17.95
40	46.20	37.27	23.02	25.42
70	79.48	63.85	39.35	42.65
		Time from NSC Oakland		
All	6.47 da.		7.49 da.	9.07 da.

TABLE III-9

Of course, the purpose of industrializing an operation (whether it be MAC, QUICKTRANS, or USPS) is to make the users conscious of costs and to minimize total costs for both the operator and the customer.

In an effort to gage the performance of the USPS, the Postal Affairs Branch in OPNAV directed an analysis of all parcels leaving NSCs Norfolk and Oakland for FPO, New York during a two week period. The results of the analysis are included in Table III-9.

Some interesting situations were uncovered by the analysis or were previously known:

o <u>All</u> classes of mail are trucked from Norfolk to Postal Concentration Center, New York. Thus, there should be no difference in service among MOM, First Class, and APP and no reason for paying more than the MOM rate. In fact, First Class is <u>never</u> used; APP, when used, appears to get Kennedy International Airport 0.45 days earlier. Inspection of the raw data suggests that this may be due to priority handling within NSC Norfolk.

Although mail dispatched from Norfolk on one day should be dispatched from Kennedy International Airport the next day, there is at least an additional day's delay due to poor truck scheduling. This delay may explain why APP moves from NSC Oakland faster than from NSC Norfolk.

Despite NSC Oakland's firm policy, almost half the parcels for the Sixth Fleet moved via MOM. Possible reasons for this are:

Workers at Oakland do not follow policy

Ships thought to have an FPO, San Francisco, address actually actually have an FPO, New York, address

Parcel express packages transported via QUICKTRANS and bound presumably for ships in the Norfolk area may be entered into the postal system as MOM if the ship is overseas.

If MOM moves by surface from San Francisco it must take a minimum of four days. Fourteen parcels that did move via surface means took 11.86 days. Yet MOM packages actually took only half a day longer than those from Norfolk. This may be because the Postal Service is moving MOM on a space-available basis by air.

Again for purposes of comparison MAC and MAC-QUICKTRANS total elapsed times are shown in Table III-9. The figures were taken from "MAC Analysis Report for Shipment Units Reported (DD-I&L(M) 782)" and QUICKTRANS Transit Time and Priority Summary 4630-19." More recent MAC times may drop slightly in the coming fiscal year and QUICKTRANS times rise.

8. Requisition Transmission Within CONUS

Between continental Naval Supply Centers and ICPs or DSCs, all IPG I and II requisitions are transmitted by AUTODIN or, if exception data are included in the requisition, by message. By comparison of the contents of computer tapes maintained at SPCC and Norfolk, it is possible to estimate the number of hours elapsing between release of a requisition by one activity's computer and its receipt by the other activity's computer. The results of analysis of 4300 IPG I and II requisitions are displayed in Table III-10. The average transit time from Norfolk's computer to SPCC's computer is 22.6 hours, from SPCC to Norfolk 16.7 hours. Note from Table III-1 that in the case of requisitions going from Norfolk to SPCC, at least 3 1/2 hours elapse when the requisition is not "on the wire." For requisitions going in the other direction, the off-wire delay for IPG IIs may be as much as 24 hours but obviously averages much less than this.

REQUISITION TRANSMISSION BY WIRE

HOURS	NORFOLK TO SPCC	SPCC TO NORFOLK	HOURS	NORFOLK TO SPCC	SPCC TO NORFOLK
1	1	93	18	32	85
2	0	6	19	78	48
3	1	57	20	32	26
4	0	29	21	33	87
5	0	177	22	46	82
6	0	155	23	26	30
7	0	128	24	171	27
8	0	124	25-28	81	108
9	6	86	29-32	81	293
10	4	136	33-36	32	129
11	71	107	37-40	34	6
12	44	106	41-44	6	9
13	14	81	45-48	41	92
14	19	251	49-52	6	17
15	134	183	53-56	38	15
16	101	212	57-60	5	3
17	110	90	OVER 60	105	260

TABLE III-10

C. Requisition Response Time

An important output of the computer programs developed for S^4 is requisition response time -- the time elapsing from mechanic's request for material to mechanic's receipt of material. Therefore, this statistic is useful not only in indicating succinctly the current performance of the material support system as a whole but in testing the overall realism of the S^4 computer simulations.

Unfortunately, there is now no operational data collection system in the Navy which routinely reports and displays this information for all corrective maintenance actions. It is possible that a data element from the Maintenance Data Collection System could be combined with information submitted to the ship's supply department to deduce requisition response time. However, at the present time neither the possibility nor the practicability of this method has been established. The casualty reporting (CASREPT) system now provides closed loop information on certain requisitions. However, the reports are limited to emergency situations, which at most embrace only three percent of all corrective maintenance actions for ships. Furthermore, response time is collected only on those parts not available aboard ship. A more comprehensive system, involving reporting of all material receipts aboard computerized ships, is now in the final stages of development. Even this will be limited to material requests leaving the ship.

In the absence of routinely available information, the study group requested three type commanders -- Commander, Cruiser-Destroyer Force; Commander, Amphibious Force; and Commander, Naval Air Force -- in the Atlantic Fleet to provide basic data on response times observed by ships recently returned from deployment in the Sixth Fleet. COMCRUDESLANT and COMPHIBLANT supplied information in the form of OPTAR logs, which indicate the Julian data of the requisition and a date approximating the receipt aboard ship. COMNAVAIRLANT forwarded key-punched data taken from the packing copies of DD Forms 1348-1. Since the AFS does not include such forms with its issues, the COMNAVAIRLANT sample was limited to requisitions supplied from CONUS and therefore, considerably biased. Hence, it was decided to include aircraft carrier observations only for 1H and 1N cog material, for which observations from other ships were severely limited.

The estimates of response time resulting from analysis of shipboard data are listed in Table III-11. Shown are (a) the number of off-ship requisitions reported, (b) the average response time for these, (c) the fraction of total demands that must leave the ship (as estimated by an Afloat Simulator to be described in Chapter V), (d) the estimated time to issue those items obtained from the ship's storeroom, and, finally, (e), the sum of (d) and the product of (b) and (c), or the estimated average response time for <u>all</u> mechanics' requisitions.

ESTIMATED REQUISITION RESPONSE TIMES

COG SYM	SHIPBOARD OBSERVATIONS	REPORTED AVG TIME	FRACTION LEAVING SHIP	SHIPBOARD TIME	EST REQN RESP TIME
1A	130	22.05 da	.492	.110 da	10.96 da
1H	551*	31.61	.538	.143	17.15
1N	417*	30.30	.527	.202	16.17
2A	49	23.67	.301	.112	7.24
2G	N/A				
2H	72	49.08	.724	.114	35.65
2N	129	31.61	.524	.183	16.75
2U	N/A				
4A	N/A				
4G	106	25.96	.434	.243	11.51
4N	105	30.91	.333	.207	10.50
9C	334	22.20	.502	.149	11.29
9G	197	14.73	.484	.180	7.31
9N	593	16.86	.411	.214	7.14
9Z	261	21.74	.442	.177	9.79

* Includes COMNAVAIRLANT Observations

TABLE III-11

IV. ASSUMPTIONS

The computer programs to be described in the next chapter are intended to simulate the material support system described in Chapter III. Exact replication of that system would require (1) the collection of vast quantities of data some of which are now available centrally but most of which either appear only in local records or have not even been reduced to raw written form and (2) the design and operation of computer programs relating these data in the exact manner specified by policy or evolving over time. Even to attempt such a comprehensive simulation would be prohibitively expensive. To succeed would imply replication of the Sixth Fleet and its material support system for a long enough period to run experiments and test policies.

High speed computer simulations are intended to test alternative policies at relatively low cost and without the replication of all or even a part of the physical system under scrutiny. To achieve this end, all simulations, including those developed in S^4, must employ simplifying assumptions about how the system behaves and what the data would reveal if invariably available. For S^4, these assumptions are stated in the following paragraphs, with evidence of the plausibility of the assumption and the consequence of its employment.

A. Requisitions Involved

For purposes of estimating requisition response time it is assumed that all end-use requisitions and only end-use requisitions are assigned Issue Priority Group (IPG) I or II. The assumption is not strictly true. Although, according to current Uniform Military Material Issue Priority Standards, all IPG I requisitions are for end-use and all IPG III are for stock, IPG II may be cited for both low priority end-use requirements and essential-item stock replenishment.

The advantage of the assumption is that all records are now routinely divided by Issue Priority Group, but not between stock replenishment and end-use. The one exception to this involves ships with computer capability, which, in effect, code the requisition number to indicate replenishment or end-use. Decoding this information for management reports requires additional programming and running time and is rarely done.

The effect of this assumption is to increase simulated response time slightly because the simulations assume a larger fraction of IPG II requisitions to be end-use than is actually the case.

B. Immediate Satisfaction of Requisitions by Issue Priority Group

It is assumed that a requisition has the same probability of being satisfied at once, regardless of the Issue Priority Group of the requisition. To test this assumption at the wholesale echelon, the approximately 1.5 million demands placed on the system in FY 1971 were analyzed to determine the fraction satisfied in each priority group. The results, displayed in Table IV-1, suggest (1) that there is little difference in the treatment given the three priorities, (2) that IPG I requisitions generally get better treatment than IPG II but (3) that IPGs I and II combined actually enjoy about 1.3 percentage points lower satisfaction than requisitions as a whole.

AVAILABILITY BY ISSUE GROUP

FY 1971

COG	AVAILABILITY				
	IPG I	IPG II	IPG I and II*	All IPGs*	Difference of Last Two Columns
2G	62.3%	57.8%	61.3%	61.3%	0%
4G	89.4	69.3	75.9	74.7	+1.3
1N	85.5	85.5	85.5	87.4	-1.9
2N	75.7	56.9	63.4	62.1	+1.3
4N	87.0	81.7	83.7	83.1	+0.6
1A	83.1	82.2	82.3	80.9	+1.4
2A	76.5	76.3	76.3	76.7	-0.4
4A	85.6	85.2	85.5	85.5	0
1H	83.3	82.6	82.8	83.4	-0.6
2H	66.6	62.5	63.6	62.9	+1.3
2U	77.5	76.1	76.7	79.5	-2.8

*Requisition weighted.

TABLE IV-1

To analyze the consequences of rationing the indicated percentage changes (where greater than 1 percentage point) were applied to estimates of requisition response time previously developed by the Synthesizer (to be described in Chapter V). The effect of using the supply availabilities in column 4 of Table IV-1 in lieu of those in column 5 is summarized in Table IV-2. The maximum error caused by the assumption is + 0.56 days response time. In all other cases, the error lies between + 0.37 days and - 0.34 days. Thus, the consequence of ignoring rationing at the ICP echelon, if it exists at all, is to increase simulated response time slightly over its true value.

Discussions with Fleet personnel as well as paragraph 2 of COMSERV-FORSIXTHFLT Message 081212Z of April 1972 indicate that no significant Fleet rationing is done to increase the probability of satisfying a high priority requisition.

CHANGES IN RESPONSE TIME

COG	CHANGE IN ICP AVAILABILITY	NEW RESPONSE TIME@	OLD RESPONSE TIME*	CHANGE
4G	+ 1.3%	13.16 days	13.33 days	- .17
1N	- 1.9	8.57	8.51	+ .06
2N	+ 1.3	32.65	32.02	- .37
1A	+ 1.4	19.22	19.56	- .34
2H	+ 1.3	23.36	23.68	- .32
2U	- 2.8	14.25	13.69	+ .56

@ Based on availabilities in column 4 of Table IV-1
* Based on availabilities in column 5 of Table IV-1

TABLE IV-2

C. Independence between Echelons

It is assumed that the gross supply availability at a particular echelon is independent of (i.e., not influenced by) availability at any other (higher or lower) echelon. Richards# has tested the validity of this assumption by means of a 3-echelon simulation involving hypothetical items and has found that, in general, demand between echelons is not independent but that, given the Navy's current stock policies, the dependence is minimal.

Drawing conclusions from the simulation, Richards states: "If an item is included in the range of items carried aboard a ship or an AFS as a demand based item, it is carried at a depth sufficient to achieve a prescribed basic combat endurance . . . Likewise, the reorder level at the stockpoint or the ICP is determined to provide a high level of protection against stockouts. The sample output reveals that gross supply availabilities are very nearly one whenever stockage levels are set in accordance with the prescribed standards."

There is a strong empirical evidence that, at the shipboard level, availability is either 100 percent or 0. Table IV-3, summarizing 18 months of Sixth Fleet demand by cognizance symbol, indicates that almost 3/4 of the items demanded satisfy one of these extreme situations. Further, the presence of mid-range availabilities is in some cases due to the addition or deletion of the item during the 18 month period. Similar results should obtain for AFS inventories, except that fewer items will have an availability of 100 percent and more 0 because of the narrow AFS range. Extreme availabilities are less likely at the ICP echelon.

Richards, F. R., A Study of Independence between Supply Echelons US Naval Postgraduate School, Monterey, California; February 1973

TABLE IV-3

FREQUENCY DISTRIBUTIONS OF ITEM AVAILABILITY ABOARD SHIP

COG	ITEM AVAILABILITY IN PERCENT*									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
1A	431	1	13	0	161	14	5	0	0	341
1H	2,285	26	126	1	546	115	68	13	0	1,372
1N	2,024	17	117	7	620	87	54	11	1	1,033
2A	107	1	1	0	14	3	0	0	0	129
2H	209	0	2	0	17	2	2	0	0	115
2N	167	2	12	0	22	7	8	2	0	189
4G	189	2	9	4	46	21	15	10	2	143
4N	197	1	15	0	26	21	17	3	2	193
9C	2,668	54	177	4	881	190	90	18	0	1,975
9G	1,798	28	133	14	762	127	70	23	5	1,062
9N	7,263	150	629	49	2,981	614	394	157	35	5,258
9Z	2,899	42	214	9	1,371	238	161	53	7	2,459
TOTAL	19,857	324	1,492	88	7,447	1,439	884	184	52	14,269
PCT	43	0.7	3	0.2	16	3	2	.4	.1	31

*Based on all demands, not just those reported as relating to specific equipment.

Richards continues: "These arguments tend to indicate that carried items will have availabilities very nearly one. Obviously the availability is zero if the item is not carried. Based on these arguments, it seems likely that the cog availability at a given echelon is primarily a weighted average of availabilities of zero and numbers close to unity. Provided this is true, the independence assumption should not critically affect the estimates of mean requisition response times.

"If the above interpretation given to the cog availability figure is not correct, and a substantial fraction of the items composing the material cognizance class have availabilities which are at neither extreme, then the estimate of cog mean requisition response time will probably underestimate the true mean response time."

It should be added that the shipboard, AFS, and screening echelons have been combined into a single Fleet Simulator, in which echelon dependence is recognized. Similarly, processing at Norfolk and the rest of the wholesale system is incorporated in a single CONUS simulator. This should mitigate the adverse effects of assuming independence.

D. Afloat Repair Pools

It is assumed that a repair pool or repair line is not used below the wholesale level. Hence at the shipboard and AFS levels all items can be treated as consumables. In fact, in contrast to aviation supply, there are few repair lines operated for shipboard equipment at the intermediate (i.e., tender) echelon. Although a tender may accept a component for repair, repair it with the ship's parts, and return it to the ship, a tender does not characteristically maintain a pool of RFI (ready-for-issue) units which can be traded for a ship's malfunctioning unit.

E. Initial Stock List

It is assumed that the COSAL (Coordinated Shipboard Allowance List) is the sole source of material aboard ship. In fact the ISL (Initial Stock List), which defines what is carried aboard ship, may include a small amount of material not in the COSAL. The extent to which these stocks affect supply availability of technical material has not been examined.

F. Operating Space Items

It is assumed that Operating Space Items (OSI) included in the COSAL do not contribute significantly to shipboard availability. To test this assumption, inventory operations aboard five of the ships in the S^4 sample were simulated first with OSI included and then with OSI excluded. The results are compared in Table IV-4. In two instances the supply availabilities with and without OSI were identical; in the other three instances they were within 3 percentage points. Note that operating-space items are predominantly items of portable and semi-portable equipage (i.e., damage control gear, fire-fighting equipment, rigging tools, etc.) Although they account for a significant fraction of the total COSAL inventory, they are not normally wearable and, accordingly, do not contribute significantly to supply availability. They are often excluded from reported

CONTRIBUTION OF OPERATING SPACE ITEMS

	INVENTORY ($000)			SIMULATED SUPPLY AVAILABILITY	
	Observed	Simulated			
		W/OSI	W/O OSI	W/OSI	W/O OSI
AO-109	152	551	218	44	43
AO-147	243	638	190	51	51
DD-862	309	501	326	48	45
DEG-4	804	1,194	857	52	49
LPA-249	361	788	304	49	49

TABLE IV-4

COSAL values, as exemplified in the "observed" figures reported by TYCOMs.

G. Sources of Stock Afloat

It is assumed that the only sources of stock afloat are (1) the ship's storeroom, (2) the AFS, and (3) other ships' storerooms via the MATCONOFF screening. In particular, the following unusual sources are excluded as being statistically insignificant:

(1) Maintenance sources.

Table IV-5 lists the total world-wide shipboard demand for parts in CY 1970* and indicates how much of that was provided from shipboard Supply Department stock and how much from maintenance sources. This latter classification encompasses cannbalization, salvage, use of next higher assembly, and outside sources, such as tender stocks. The total input from maintenance sources is obviously quite small. If material from maintenance sources had in fact been available through the supply department, the gross supply availability would have risen less than 1 percent in each commodity.

(2) Shipboard substitution.

A study# of COSAL support reveals that the use of substitute items at the shipboard level is basically the result of receiving substitute items from a stock point. For example, the DDG-2 experienced 12,468 usages of items during a 42 month period. The total number of incidences of usage of substitute items represented

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* Extracted from Mean Supply Response Time; Second Generation: 3-M MDCS Study Effort for CY 1970; U.S. Naval Maintenance Support Office; Mechanicsburg, PA; June 1971

Investigation of COSAL Configuration File; OA Report 76; U.S. Naval Fleet Material Support Office; Mechanicsburg, PA, 31 January 1972

DISTRIBUTION OF MATERIAL USAGE BY COG AND SOURCE

COG SYM	TOTAL DEMAND	SUPPLY ISSUES	MAINTENANCE SOURCES
1A	12,909	5,146	121
1H	84,989	49,892	558
1N	48,820	26,051	423
2A	3,818	2,135	6
2G	15	3	0
2H	4,960	2,310	34
2N	5,766	3,341	12
2U	322	222	0
4G	8,417	3,412	24
4N	5,836	2,790	11
9C	123,376	73,883	858
9G	74,108	45,315	595
9N	336,500	261,861	1,886
9Z	152,186	103,291	1,434

TABLE IV-5

approximately 6 percent of the total. In no case were any of the substitute items found to have been originally on the allowance list. Discussion with shipboard personnel and review of shipboard records indicate that once a substitute item is received the tendency is to reorder the substitute in lieu of the original item.

(3) Hampton Roads screening.

Screening of ships in the Hampton Roads area, although quite important in individual maintenance actions, is limited to assets not visible to the ICPs and involves items which have long lead times or have been a source of availability problems in the past. Statistically, the screening is insignificant, involving only 337 searches in the first half of CY 1971 for all Atlantic Fleet requirements.

(4) Shortages and Valuable Excesses (SAVE) Program.

SAVE is essentially a swap-between-ships program to permit a ship to fill deficiencies in its allowance by transferring material at no cost from a ship having an excess. Because Type Commanders have characteristically funded deficiencies in demand based items, the program is essentially limited to insurance items. For Fiscal Years 1970, 1971 and 1972 less than 9,000 line items, valued at under $500,000, were swapped annually among all ships of the Atalntic Fleet. This appears statistically insignificant for S^4.

The effect of ignoring the above unusual sources of supply will be to increase simulated requisition response time slightly above its true value.

H. Sources of Stock in CONUS

It is assumed that the only sources of supply in CONUS are (1) stocks immediatley available in the wholesale system (including NSC Norfolk), (2) receipts from previously let contracts or repair orders (3) spot repairs and (4) spot purchases. The following sources are specifically excluded:

(1) Cannibalization.

During FYs 1971 and 1972, cannibalization actions for the entire Atlantic Fleet averaged 322 per year for ESO material, 192 for SPCC material.

(2) Substitution.

Analysis of requisition history files at ESO and SPCC indicates that a true alternate FSN is used 0.84 percent and 1.9 percent of the cases, respectively, to satisfy a material request reaching the ICP. In additional cases, included in both the Afloat and CONUS S^4 Simulators, requisitions are satisfied by issuing a superseded or superseding FSN or by finding an FSN for a part numbered requisition.

(3) Locally Controlled Material.

Only in 1H and 9C cogs are there any locally controlled items that might contribute to support of the Sixth Fleet. Six percent of 1H requisitions are for A fraction (centrally catalogued, locally managed) items; in April 1972 about 1/3 of 9C sales were for L fraction (locally catalogued and managed) items. In the case of 9C items only about 10 percent were other than lumber or plywood and thus might be equipment related; about 1/7 of the 1H cog items had names that suggest equipment relationship.

The effect of ignoring the above sources is to increase slightly the simulated requisition response time.

I. NRFI Return Rate

It is assumed that (1) return of a not-ready-for-issue (NRFI) component occurs only after a recurring demand occurs and that (2) the probability of return is the ratio of NRFI return rate to recurring demand forecast. Although there is no evidence to prove that this is the correct approach, discussions with personnel in the field of repairable item management suggest that it is acceptable.

J. Exponential Servicing Times

It is assumed that the distribution of time to service a single requisition/material at a single work station is exponential. No specific evidence has been accumulated to prove or disprove this. However, it is an assumption widely and successfully used in queuing theory.

K. Processing Sequence

It is assumed that personnel with several functions always give first priority to the processing of IPG I and II requisitions or the material related thereto. Although this assumption has not been verified by observation, it is a reasonable assumption, given the mission of the Naval Supply Systems Command and its constituent activities.

L. Item Importance to Repair

It is assumed that all failed items must be replaced in a corrective maintenance action. While there is no strong evidence supporting this assumption, there is lack of evidence of the contrary assumption. No item essentiality rating scheme yet developed and in practical use has identified more than a small fraction (5 - 10 percent) of the items as being other than vital to the operation of an equipment.

M. Single Delayed Requisition

It is assumed that when a mechanic requisitions material serially for a repair instead of concurrently (as happens in about 43 percent of the repairs involving 2 or more parts). (1) only 2 batches of requisitions are submitted and (2) one batch contains only 1 requisition. Although there are some instances in which serial requisitioning does not adhere to the n-1, 1 or 1, n-1 pattern, using such a pattern in simulation results in 97 percent of the repair actions being correctly modelled.

N. Poisson Arrival Distribution

It is assumed that the distribution of requisition arrivals at each work station or activity is Poisson. Because scheduling rules cause requisitions to be batched, this assumption is clearly not an exact representation of reality. However, it can be shown that the more realistic assumption that inputs are at constant intervals in batches whose random sizes are Poisson can be well-approximated by a Poisson process. This is demonstrated through the following argument:

Pr {a total of n units have arrived on or before the end of the kth uniformly spaced interval}

$= Pr\{$ k modules of random and Poisson-distributed size lead to a total of n $\}$

$= Pr\{$ sum of k Poissons totals n $\}$

But it is well known that k identical Poissons with parameter <u>a</u> sum to another Poisson, this one with parameter <u>ka</u>. Hence,

$Pr\{$ sum of k Poissons totals n

$$= e^{-ka}(ka)^{n}/n!,$$

that is, Poisson with mean <u>ka</u>. In view of the facts that the system will not be able to react immediately to the input and that the time between batches can be lowered, the overall process (not just that evaluated at a point of arrival) will largely act as a Poisson process even though the proved result is not valid for times between batches.

A routine was developed during the study for testing whether any particular set of data are Poisson distributed. The procedure uses the well-known Kolmogorov-Smirnov statistics. The technique is: given a sample of N observations, $D = \text{maximum}_x \{Q(x) - S(x)\}$ is determined where Q(x) is the cumulative Poisson distribution function with mean rate taken to be the sample mean and S(x) is the sample cumulative distribution function. If the value of D exceeds a known tabulated critical value at the 5 percent level of significance, then the hypothesis of "Poissonness" is rejected.

Requisition arrivals at each work station at NSC, Norfolk, were tested by the above procedure; in no case could the hypothesis that arrivals were Poisson distributed be rejected.

O. <u>Shipboard Maintenance Practices</u>

It is assumed that current shipboard maintenance practices will remain in force and hence that average demand rates will remain constant over time. Revised maintenance practices can be modelled only to the extent that the effect of revised practices on demand rates can be externally estimated and provided to the afloat and CONUS demand generators.

V. DESCRIPTION OF COMPUTER PROGRAMS

The supply and resupply organization and procedures described in Chapter III and simplified by the assumptions stated in Chapter IV are modelled in a series of 5 computer analyzers and simulators.* The outputs of these computer programs are:

° The gross supply availabilities attainable at each of eight echelons for each of 15 classes of material if specified inventories are held at each location.

° The time required for a requisition and the material resulting therefrom to complete the several legs of its journey from the mechanic to the echelon having stock and back to the mechanic.

° The requisition response time as the mechanic views it, given that each echelon supplies a part of the mechanic's total needs.

° The supply response time -- the time required to collect all the parts needed for a corrective maintenance action.

° The operational availability, or up-time, of a particular nomenclature of equipment based on the supply response time developed above plus other characteristics.

The remaining sections of this chapter describe broadly the construction, inputs and outputs of each computer program and show how they are linked together to produce the outputs enumerated above. Technical details of the programs appear in Appendix C.

A. Overview

Figure V-1 displays the interconnections, flow of data, and general outputs of the five simulators and analyzers developed in S³. The Afloat and CONUS Inventory Simulators require as inputs the demands imposed on each echelon, the inventories available at each echelon and the policies employed in satisfying demands and replenishing stock. The computer first combines these inputs in a stream of issue and receipt events covering thousands of items and several years and then analyzes the events to estimate resulting inventory levels, resupply and issue workload, and gross supply availability.

The Process Analyzer, using engineered or estimated time standards, models of requisition and material flow within an organization, and

* An analyzer evaluates mathematical expressions describing the relationship between input(s) and output(s): a simulator generates a stream of events according to specified rules; and, by tallying results, calculates and displays a possible relationship between inputs and outputs.

SCHEMATIC OF SUPPLY SYSTEM SIMULATOR

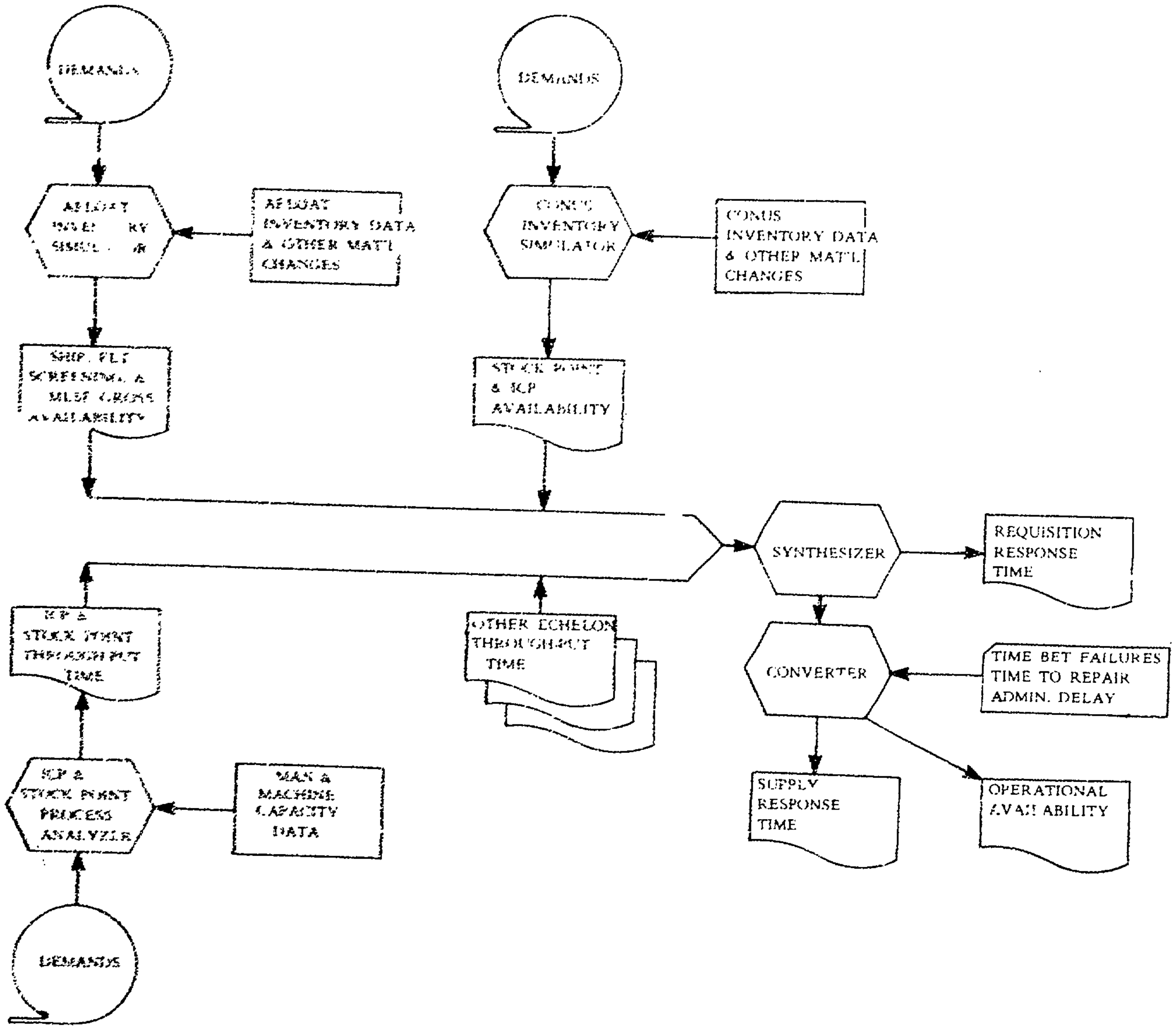


FIGURE V-1

various doctrines concerning batching, scheduling, and transporting, produces a statement of the probability that a requisition or material will be completely processed through an organization in a specified time, ranging from 1 hour to 360 days. New probabilities can be computed in response to changes in workload or organizational capacity. Where the process cannot be modelled in detail for unavailability of data, existing reports can be analyzed or special studies made to deduce throughput probabilities directly.

The Synthesizer combines the outputs of the Inventory Simulators and Process Analyzers to produce estimates of (1) the distribution of requisition response time, (2) workload (issues, receipts, orders, and items carried), (3) inventory levels and (4) average, incremental, and marginal costs. Note that the division between afloat and ashore processing implicit in the inventory simulators is retained in the Synthesizer. Thus, a specific requisition unfilled in the Sixth Fleet is not transmitted to NSC Norfolk but is "killed" while a new requisition is generated for the wholesale system. This approach is satisfactor as long as (1) the basis for generating CONUS requisitions is the net demand of fleet and other customers -- which it is -- and (2) the Fleet and CONUS systems can be considered statistically independent -- which the discussion in Section IV C indicates they nearly are.

The distribution of requisition response time, transferred manually to the Converter, is used in simulating corrective maintenance actions on a particular equipment to construct an estimate of supply response time -- the time needed to assemble all parts for a given repair. Other necessary information, including a profile of an equipment's maintenance actions, its average time to repair and its average time between successive failures, is obtained from the 3M Data Collection System either directly or through special studies. The final output of the converter is the operational availability, or average up-time of the equipment and the change in up-time that would result from changes in supply response time.

B. Afloat Inventory Simulator

The Afloat Inventory Simulator emulates the inventory management functions performed in the Sixth Fleet, modelled to consist of 28 sample ships, an AFS, and a notional ship which probabilistically describes the support capability and requirements of the balance of the Fleet. The model replicates the activity among the elements of the Fleet through the occurrence of events which define relationships ng system variables and which, when executed, change the values of these variables and thus the status of the system. The ensuing discussion explains the functions of the events in this model and briefly describes the inputs and outputs.

1. Events

a. Demand event - This event is the primary impetus of the model.

It occurs when a requirement is placed on an inventory by a customer and has four attributes which provide the model with the necessary processing information. These are:

° Time. Date of occurrence within the simulation as determined by the procedure described in Appendix C.

° Source. Identifies the inventory upon which the requirement is to be placed initially.

° Quantity. Identifies the amount of material needed to satisfy the requirement. Computed as described in Appendix C.

° Type. Identifies the kind of requirement that is being placed -- end-use, fleet screening or resupply.

The following is a description of how the model handles each of these requirements.

(1) End-Use requisition.

The inventory of the ship is checked to determine if material is available to satisfy the requirement. This results in the following:

° Sufficient material available. The requirement is assumed satisfied; material available for future requirements is reduced by the amount of the requirement.

° Sufficient material not available. The amount available is issued, the on hand is reduced to zero, and a determination is made as to whether the remaining item requirement should be submitted to the fleet screening process.

° No material available. A determination is made as to whether the requirement should be submitted to the fleet screening process.

(2) Fleet screening requisition.

Once it has been determined that a requirement is to be submitted to fleet screening, it is necessary to introduce the requirement to the screening process. This process entails the following search:

° FILL (Fleet Issue Load List) Item - An attempt is made to satisfy it from the AFS. If sufficient material exists on the AFS, the requirement is satisfied and the AFS stock is reduced by the quantity requested. If stock is not available on the AFS, the requirement is submitted to the screening of sample ship inventories.

°FILL item, not available from the AFS, or Non-FILL Item - The inventories of the sample ships are searched to attempt to satisfy the requirement. If it is satisfied, the material available on the satisfying ship is reduced by the amount of the requirement. If stock is not available from the sample ships, a further attempt is made to satisfy the requirement from Sixth Fleet ships not in the sample, as described below.

° Not available from the AFS or the sample ships - An attempt is made to satisfy the requirement from ships outside the sample. This is done by drawing a uniform random number between zero and one. If the value of this number is less than the probability that a ship outside the sample will satisfy a screening requisition, the requirement is assumed satisfied. Otherwise, material will be ordered from CONUS. Receipt of material will be determined on the basis of a random draw from a probability distribution.

(3) Resupply requisition for FILL material

A resupply requisition is placed on the AFS for FILL material. These requirements are serviced on a FIFO basis; it is assumed there is no rationing of material. The requirement may be satisfied in whole or in part. The inventory of the AFS is reduced by the amount of the requirement satisfied, and the requesting inventory is increased by the amount provided by the AFS.

During the occurrence of this event, the variables necessary to compute the availabilities produced as simulation output are incremented and other events are caused to occur.

b. Inventory review event - The basic functions of this event are to review the demand history of an item to determine the basis for an item's inventory level and to compute the appropriate inventory level. This event is triggered after every demand on the ship and every 30 days on the AFS.

(1) Demand review - The past demand history and the current item status (demand-based or not) are reviewed.

° If the item is currently not demand-based, the number of demands recorded in the past history is computed and compared to the number of hits required for demand-based qualification. If the number of hits is greater than or equal to the number defined for demand-based qualification, the item becomes a demand-based item. If it is not, the item remains a non-demand-based item.

° If the item is currently a demand-based item, the number of demands received in past history is compared to that needed for an item to continue being demand based. If the observed quantity is greater than or equal to the required quantity, the item continues to be a demand-based item; if not, the item reverts to being non-demand based.

(2) Inventory levels

There are three methods of computing inventory levels in this event:

o Levels for non-demand-based items. These levels are determined from the allowance quantity. The requisitioning objective equals the allowance quantity; the reorder point is one unit less than the allowance quantity.

o Levels for sample ship demand-based items. These levels are computed as described in Appendix C. The variables used in the computation are the average monthly demand, the high limit factor, and the low limit factor.

o Levels for AFS Demand Based Items: These levels are computed as described in Appendix C. The variables used in the computation are average monthly demand, operating level multiplier, operating level constraints, safety level factor, and order and shipping time factor.

c. Review of assets event - The function of this event is to review the status of an item's assets in light of inventory levels as determined during the inventory review. An order is placed if the assets are less than the reorder point or if the item has had an end-use requisition and there was no material on hand. These orders are placed on the CONUS system and the time of receipt of the material is determined by a draw from a probability distribution of receipt times.

There are three different types of orders which require draws from different distributions of receipt time. These distributions represent times for:

o A normal resupply requisition to be received.

o An end-use requisition for material to be directly turned over to the requirer and not picked up in inventory.

o A normal resupply requisition for an AFS.

During this event the statistics concerning number of resupply orders generated are accumulated.

A special case of reordering material occurs within the sample ships when the item is to be ordered from the AFS. In essence, the same procedure as described above is used, but orders are placed on the AFS in the form of a demand. These demands are then processed as a requirement for FILL material.

d. Receipt of material event - This event occurs when the material ordered in the previous event arrives aboard ship. When the material is received, a determination is made whether or not the order is resupply or end-use. If it is end-use and the requirement still exists, then the receipt is not taken up in inventory. If it is a resupply order and there are outstanding end-use requirements, an attempt is made to satisfy the requirement, with any residual amount taken up in inventory.

2. Input.

The input required for the execution of the model consists of item data which define the attributes of each item simulated. These attributes include cognizance symbol, stock number, unit price, allowance quantities, and demands (described by date of occurrence, type and quantity). The values of these data are obtained by synthesizing four basic sources of information in a series of pre-processing programs which prepare the simulation input.

The management data (cog, stock number and unit price) are derived from an updated version of the COSAL candidate files for the sample ships. These files contain the basic list of all items installed on the sample ships. The allowance quantities are also developed from these data sources by producing COSAL quantities for each of the items on the sample ships. These COSAL allowance quantities become the initial on hand stock at simulation day zero for each of the items on the sample ships. The allowance quantity for the AFS, which is also considered the initial on hand stock on simulation day zero, is obtained from the FILL published by FMSO.

The other data produced by the pre-pocessor programs are demands which will be placed on the sample ship and AFS inventories. These demands have attributes of time, source, quantity, and type. The pre-processor produces the demands used in the simulation by the model described in Appendix C. In order to use this procedure, it is necessary to have two parameters which describe the specific item as it is demanded on a specific ship. These parameters are "mean time between requisition arrivals" and "average requisition size." The development of these parameters requires the use of two other data files. The demand parameters for the sample ships are developed from the 3M parts usage data recorded in the 3M MDCS, while the parameters for the AFS demand from ships outside the sample are developed from the Load List Demand History File maintained by FMSO.

3. Output.

The normal execution of the Afloat Simulator provides various sets of data which are applicable to a single cognizance of material. The sets consist of synthesizer input requirements, snapshot data, and item output data.

a. Synthesizer input data - Because the Afloat Inventory Simulator actually models three echelons, (i.e., ship, MLSF, and screen) it must produce the data input for three echelons. Table V-1 (see next page) identifies the synthesizer requirements produced by the simulator for each echelon by an x opposite the corresponding statistical element.

DATA FOR SYNTHESIZER

DATA ELEMENT	TRANSIENT SHIP	TRANSIENT MLSF	TRANSIENT SCREEN	STEADY STATE SHIP	STEADY STATE MLSF	STEADY STATE SCREEN
Number of Items Carried	x	x		x	x	
Number of Requisitions/Year	x	x	x	x	x	x
Value of Annual Demand	x	x		x	x	
Average Value of Inventory	x	x		x	x	
Average Value of In-transit Inventory/Year	x	x		x	x	
Number of Resupply Orders/year	x	x		x	x	
Availability	x	x	x	x	x	x
Issue Time	x			x		

TABLE V-I

This table shows that there are actually two sets of indicators: transient and steady state. The former are those applicable to the first year of simulation and the latter represent an average of the last three years of simulation.

The screening echelon displays only two data elements which are required by the synthesizer. This is due to the fact that screening is not actually an echelon of supply and has no inventory; accordingly, the various elements of inventory statistics are not applicable.

b. Snapshot data - On predetermined dates snapshots of the value of various elements of the inventory are taken in order to compute the indicators required by the synthesizer. The values obtained by these snapshots could also provide pertinent data to an analyst. These raw values are provided by the simulator and take the form of a matrix with elements representing the value of interest for a specific ship at the time of a snapshot.

c. Item output - If an individual FSN is identified in the simulation input as requiring item output, the simulator will produce three types of output records:

° Screening - An item record is produced which identifies the item, the number of screening demands, and the availability provided by screening.

° AFS - An item record is produced to identify the item, whether or not it is stocked, the average number of requisitions received per year, the availability provided, the average on hand quantity, the allowance quantity, and the average annual demand.

°Ship - For each ship simulated an item record is produced to identify the item, whether or not it is stocked, the average number of requisitions received per year, the availability, the average on hand quantity, the allowance quantity, and the average annual demand.

C. CONUS Inventory Simulators

Two separate ICP simulators have been designed to account for minor variations in requisition processing between ESO and SPCC. For the most part, however, the two simulators are identical. An attempt has been made to duplicate the current UICP decision rules for consumables and repairables as closely as possible within the limitations of computer core space and running time. The refinements excluded are (1) the demand filter used to discount extreme demand values, (2) the Mark migration filter, used to reduce migration from one decision rule to another, and (3) calculation of quantity discount benefit. In addition, it is assumed that no program changes occur and that there are no demand trends.

1. Inputs

The inputs for the ICP simulation all come from the Uniform ICP Automatic Data Processing System. Source files include the Stratification Preliminary Work Tape (File B20DX1), the Selective Item Extract Generator (U40KX1), the Demand History File (B18FX3), and the Transaction History File (B18JX1). Over 50 specific pieces of information are required, including system and activity demand (replenishable and non-replenishable), demand variances, system and activity inventory positions, various leadtimes, and several cost factors.

2. Simulation Procedure

By analysis of the past 24 months history in the Transaction History File, it is possible to calculate system and NSC Norfolk demand rates. Both rates are subdivided between replenishable and non-replenishable; Norfolk's demands are further subdivided between demands that are submitted directly to Norfolk (i.e., POE or point of entry) and those submitted to Norfolk's satellite activities, those stock points which are not replenished but which issue available stock until it is exhausted and whose customers are supplied from NSC Norfolk thereafter.

From demand rates thus developed a demand generator creates a five year string of demands on the system and on Norfolk for a given item. (Details of demand generation are contained in Appendix C.) In addition, the following two ratios are developed separately for replenishable and non-replenishable demand:

° Norfolk POE demand to system demand

° Norfolk and satellite activity POE demand to system demand

Therafter the following events complete the simulation of a given item:

a. Start event - Daily demands and requisitions generated above are entered into the simulation during the event START. In this event all demands for an item are scheduled for the entire period to be simulated. All item data are read in and all constants and initialized values are set. Control of the program is then passed to an embedded timing routine so that events affecting the current item being simulated will occur in an orderly time-oriented fashion.

b. Demand event - When a requisition is placed against the system, an event called DEMAND will be executed. The first step is to create a random number. If this is less than or equal to the first of the two ratios given above, the demand is assumed to be a Norfolk POE demand. If the random number lies between the two ratios, the demand will be assumed to be lodged against one of Norfolk's satellite activities. A higher random number indicates that the demand was placed on an activity not specifically modelled. Norfolk POE requisitions will be filled from the combined assets of Norfolk and its satellites; if stock is not available, the requisition is forwarded to the system. Point-of-entry requisitions on Norfolk's satellite activities are handled in a similar manner except that satisfaction of the requisition merely reduces Norfolk's gross supply availability. Finally, a demand whose associated random number is greater than the larger of the two ratios given above will be satisfied from that part of the system outside Norfolk and its satellites. If it cannot be satisfied in this manner, it will then be referred to Norfolk. If sufficient stock is not available anywhere in the system to satisfy any of the demands described above, the on-hand is reduced to 0 and a backorder is established for the unfilled part of the requisition. If no stock is available, a backorder, spot-buy, or (if the item is repairable) a spot repair is simulated according to the general rules described in Chapter III. Because these rules depend partly on the issue priority group of the requisition, it is necessary in the course of demand generation to select an appropriate priority.

c. Review event - An event called REVIEW compares the item's assets to its reorder point. If assets are at or below reorder level, for consumable items a buy quantity (deficiency + EOQ) is computed, a leadtime in days is generated and the buy quantity is added to the due-in-from-contract quantity. For repairable items a decision is made to repair only, repair and buy, or to buy only. Included in the reorder point are planned programs, established as a result of transaction item report analysis in proportion to demands generated. These are held in the file for a specified length of time and then cancelled on the assumption that the program has been consumated and stock has been withdrawn.

d. Receipt and Break event - A RECEIPT event is scheduled to occur at the end of the leadtime or repair time generated when REVIEW indicates that more material is to be bought or repaired. In addition, to account for RFI material returned to store, a partial receipt event is generated whenever a demand occurs.

For non-RFI carcasses the event BREAK generates and schedules the turn-in of not-ready-for-issue material. It is assumed that non-RFI turn-ins occur one unit at a time and are evenly spaced during the quarter. The initial estimate of the number of turn-ins per quarter is taken from the Master Data File. Subsequent actual turn-ins are generated from a mean whose value is an exponentially smoothed estimate from generated values. The leadtime for a stock procurement is generated in the same manner as the quantity of turn-ins. Repair turn-around-time, on the other hand, is assumed to be constant.

e. Update event - The event UPDATE occurs every quarter and contains the UICP levels setting decision rules for EOQ and reorder point.

3. Outputs

The CONUS Inventory Simulators produce a great amount of output information for special studies, as does the Afloat Simulator. That information specifically intended as input to the Synthesizer is shown in Figure V-2.

D. Process Analyzer

The Process Analyzer consists of a series of computer and manual operations designed to calculate the average and distribution of time required to process requisitions and material through any possible journeys they may follow within a single organization. At present only NSC Norfolk, the Electronics Supply Office, and the Ships Parts Control Center have been modelled. For other organizations throughput times have been observed, not calculated, because either (1) the activity is outside the Navy or (2) necessary data collection for other activities within the Navy would be prohibitively expensive or would interfere with operations. However, there is no reason in principle why any activity in the support system could not be modelled if data on capacities, workload, and requisition/material flow were available.

1. Inputs

The Process Analyzer accepts the following data:

° Definition of system elements - the work stations that can possibly be involved in requisition/material processing;

° The frequency with which work units leaving an element arrive at each possible next destination;

° The work unit capacity of each element:

° The work load of each element

ICP - S^4 MARK II SIMULATION MODEL - ALL ITEMS

ICP SIMULATION FOR SPCC-2A on APR 1972

Total Items Simulated 6 Number of Items not Carried 0

Year	Total Reqns	Reqns($)	Non-RD Reqns	($)Non-RD	No HI PRI Reqns	($)HI PRI Reqns	No.Reqns Short
1	34	21348.	0	0.	22	11428.	5
2	31	19573.	0	0.	23	16065.	3
3	29	22743.	0	0.	18	15088.	3
4	33	24221.	0	0.	22	19215.	6
5	29	18490.	0	0.	17	3940.	3
TOTAL	156	106375.	0	0.	102	70736.	20

Availability Statistics

Year	No. Backorders	($)Backorders	No. Reconsignments	($)Reconsignments	No.Spot Buys	($)Spot Buys
1	0	0.	1	500.	3	5700.
2	1	370.	1	2280.	0	0.
3	0	0.	0	0.	3	5700.
4	0	0.	1	1140.	5	11416.
5	0	0.	0	0.	1	2280.

Year	No. Spot Repairs	($) Spot Repairs	Reqn Eff-%	Sales Eff-%	Backorders Outstanding	($)BO Outstanding
1	1	1140.	85.29	65.62	0	0.
2	1	2280.	90.32	74.81	0	0.
3	0	0.	89.66	74.94	0	0.
4	0	0.	81.82	48.16	0	0.
5	2	4560.	89.66	63.01	0	0.
TOTAL	4	7980.				

FIGURE V-2

2. Procedure

The steps described below are needed to compute throughput time probabilities from the data listed above:

a. Manually modify the frequency distribution of flows so as to avoid the possibility of a piece of work looping indefinitely through a group of two or more work stations. This is done by creating a new "dummy" element which accepts the work unit before it can begin its second loop through the system.

b. By means of a matrix power series program, compute (1) the work units reaching any given element as a proportion of those leaving any given element and (2), in particular, the work units loaded on a given element as a percent of those entering the system.

c. Observe or estimate work capacity for each station. This may be accomplished (1) by a methods engineering analysis, (2) by a test of output under maximum workload conditions or (3) by computing the maximum rate (units per man-hour) observed over a sufficiently long period and multiplying it by the maximum personnel available for the function during the same period. The last technique has been used in S^4.

d. Feed the information from b and c above into a 3-priority computerized queuing model, which calculates the probability that a unit of work will clear a single element (work station) in a specified number of hours.

e. Determine the possible paths that a requisition (or material) can follow, the work stations cleared in each path, and the probability that a requisition will follow a specified path. For small systems (reasonably, those composed of 20 elements or less) this path analysis can be accomplished by hand. For more complex systems, such as those encountered at ESO and SPCC, a path analysis program has been written. A path is a sequence of elements that a requisition or corresponding material may feasibly encounter. A path is always initiated by an element which receives a work unit from outside the system and terminated by an element which passes the work unit on outside the system. The probability of a path's occurring is calculated by taking the product of the probabilities of the various flows among the elements which comprise the path.

f. Calculate the probability that a requisition/material will complete an entire path in a specified number of hours. Institutional factors with respect to batching or other system delays not relating to the actual servicing of a work unit are taken into account at this point. The waiting times per work unit are amended to account for such waits as appropriate. For example, if requisitions leave an element every 2 hours and the waiting time distribution is with respect to each hour, then an amended distribution is constructed showing zero probability on the odd hours and the sum of the current and the previous hour probability on the even hours. If work units must wait in an element for a fixed average time independent of servicing, then the entire waiting time distribution is "shifted" forward in time by that average wait.

PROCESS ANALYZER OUTPUT

Leg Nr: 57
Time Dimension: hr.

Workload value:	-20%	Current	+20%
Mean Time:	7.760	7.765	7.777
x(in hrs)		Prob (time = x)	
3	.059	.059	.059
4	.081	.081	.081
5	.193	.191	.190
6	.176	.176	.176
7	.102	.103	.103
8	.061	.062	.062
9	.045	.045	.045
10	.042	.042	.042
11	.042	.042	.042
12	.042	.042	.042
13	.042	.042	.042
14	.042	.042	.042
15	.034	.034	.034
16	.028	.028	.028
17	.009	.009	.009

FIGURE V-3

g. Using the probability from step e that a requisition will follow a given path and the probability that it will clear the path in a specified time, compute the frequency distribution of requisition throughput time and the average throughput time for the system as a whole.

3. Output

Figure V-3 displays the output of the Process Analyzer for the flow of requisitions through NSC, Norfolk. Similar distributions are computed for ESO and SPCC. Note that the standard output, intended as input to the Synthesizer, contains not only the frequency distribution of throughput time given current workload but also the distributions that would result from 20 percent increase and 20 percent decrease in workload.

E. Synthesizer

The function of the Synthesizer is to evaluate requisition response time, given estimates of gross availability and throughput time at each echelon using the following general expression for response time:

$$R = a_1 t_1 + \sum_{j=2}^{n} \left[\prod_{i=1}^{j-1} (1-a_i)\, a_i t_i \right]$$

where: a_i = probability of satisfying a demand placed on the ith echelon for a typical item included in one of the 15 commodities managed by the inventory control points modelled.

t_i = average time to satisfy the demand (from mechanic's request to mechanic's receipt) given that the demand is satisfied by the ith echelon.

In addition, the Synthesizer:

° stores inventory and throughput time data for each cog symbol and each echelon

° produces histograms as well as expected values for requisition response time

° computes incremental resource requirements for different levels of performance.

The Synthesizer performs on a Navy-wide scale some of the functions which the Process Analyzer handles within an organization. Other values calculated by the Processer Analyzer are required as inputs to the Synthesizer. For example, the possible reouisition/material paths are determined for the Synthesizer and recorded in the path table, described below. The probability that a particular path is used is a function of the gross supply availabilities at each echelon, calculated in one of the two Inventory Simulators. The probabilities of completing a leg in an overall path in specified times are either observed or computed in the Process Analyzer and in either event, are lodged in the Synthesizer's leg tables. Given this information, the Synthesizer, as does the Process Analyzer, calculates by convolution the distribution of throughput time for an entire system path and then weights the distribution according to the probability of occurrence.

1. Inputs and Files.

The Synthesizer requires an input certain of the outputs of the two Inventory Simulators and the Process Analyzer. The data from these computer programs are stored in the Synthesizer's inventory file and throughput file, described below.

a. Inventory file - the inventory file is divided into the echelons analyzed in the Afloat and CONUS Inventory Simulators. Within echelon, the file is divided into 15 cognizance symbols and 1 or more cases. Cases generally represent specific inventory doctrines prescribing range and depth rules.

MODELLED

FLOW OF REQUISITIONS AND MATERIAL

IN THE TECHNICAL SUPPORT OF SIXTH FLEET

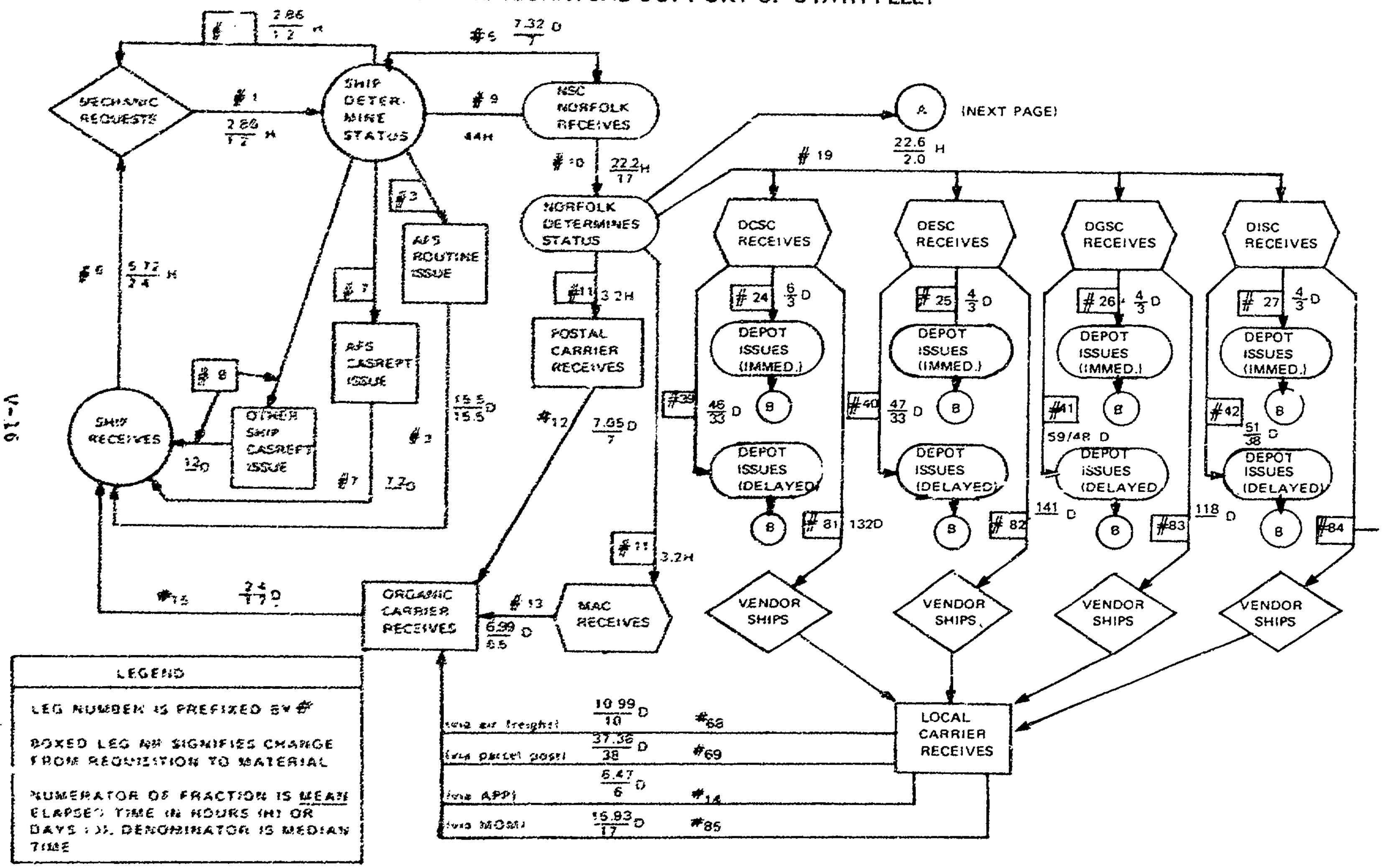
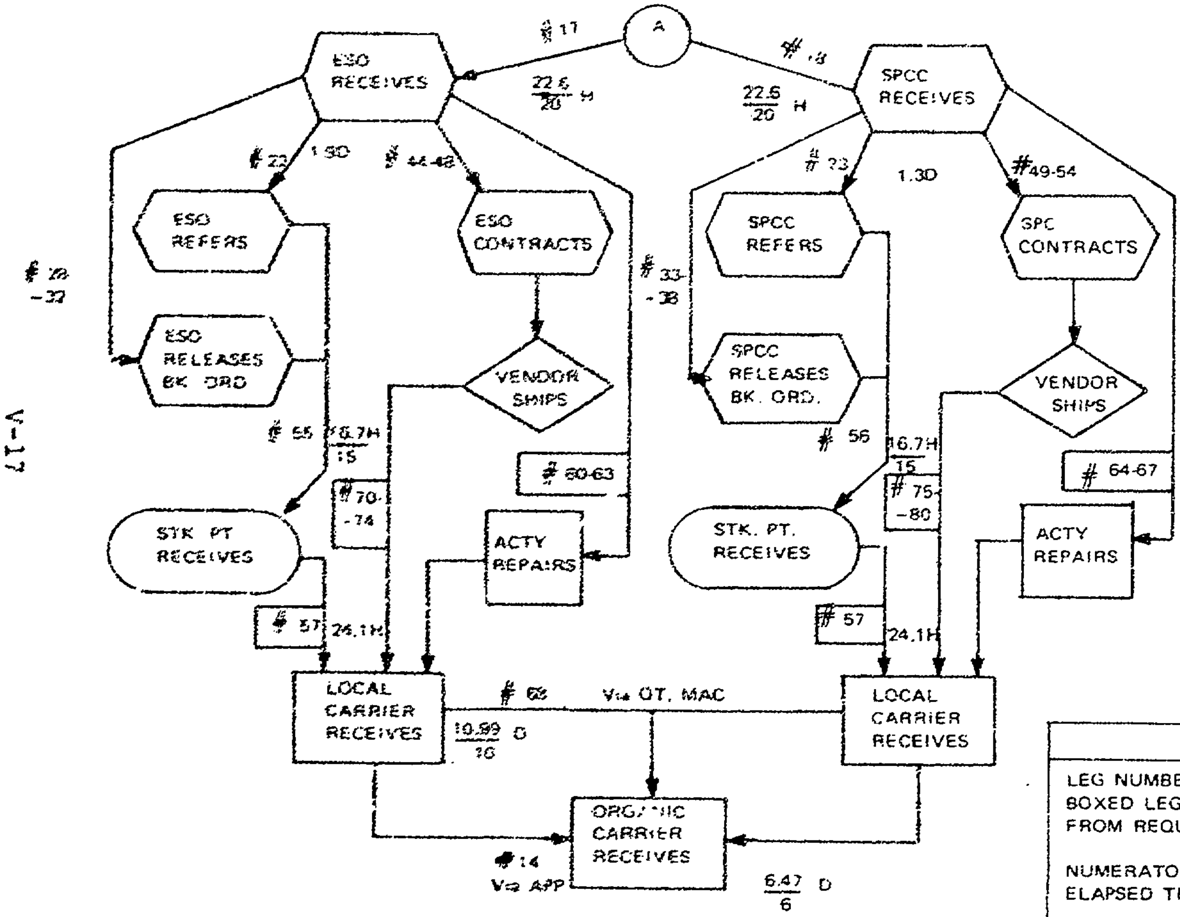


FIGURE V - 4

MODELLED
FLOW OF REQUISITIONS AND MATERIAL
IN TECHNICAL SUPPORT OF SIXTH FLEET



LEG	COG	MEAN	MEDIAN
28	2G	51.5D	40D
29	4G	116.9	66
30	1N	112.4	84
31	2N	141.8	120
32	4N	148.7	100
33	1A	110	105
34	2A	98	75
36	1H	88	66
37	2H	142	135
38	2U	65	75
44	2G	32.2	8
45	4G	139.4	106
46	1N	104.4	68
47	2N	125.9	68
48	4N	95.0	24
49-54	SPCC	See legs.	75-80
60-67	All	203	174
70	2G	33.0	—
71	4G	115.8	—
72	1N	83.5	—
73	2N	100.8	—
74	4N	97.2	—
75-80	SPCC	114.1	83

LEGEND

LEG NUMBER PREFIXED BY # BOXED LEG NR. SIGNIFIES CHANGE FROM REQUISITION TO MATERIAL

NUMERATOR OF FRACTION IS MEAN ELAPSED TIME IN HOURS (H) OR DAYS (D)

For each case there is a data table. The contents of the table vary by echelon but, in general, include, for five values of a control parameter, various input, output, cost and performance values for either the first year or the steady state (average of last three years). The control parameter varies by echelon and by case (i e., days endurance at the shipboard level, shortage cost at the ICP level) and includes a base value, at least for the base (i.e., current rules) case.

b. Throughput file - The throughput file consists of two parts:

(1) The path table, which defines for each echelon and each cog symbol the legs through which requisitions/material for a specified cog symbol must travel if they are satisfi d by a particular echelon. The objective of breaking paths into le s to permit quick assessment of changes in throughput time in parts o the system without recomputing all throughput times for all cogs for all echelons and reentering data into the computer. A single leg may be common to the path for several echelons; all cog symbols may move over ne same leg or may have unique legs. The path for an echelon-cog symbol combination may contain only one leg or may be the sum of several legs. The path table, once constructed, should seldom change. The legs modelled in S4 are portrayed in Figure V-4.

(2) Leg tables, which describe certain cost and time characteristics of a leg and contain the probability that requisitions/material will flow through the leg in a given time. Specifically, each leg table contains the following data:

° Table number

° Relative workload contribution of referrals and issues.

° Dimension of time data (i.e., hours or days)

° Mean throughput time for the leg

° Incremental cost (either positive or negative) needed to achieve the performance described by the path and echelon at which cost is incurred.

° Appropriation which would bear incremental cost (i.e., OPN, O&MN, RDT&E).

° Code to indicate whether cost is one-time or recurring.

Probability that throughput time for the leg has a specified value

2. Computations

Specific computations executed by the synthesizer programs are described in Appendix C. The calculations follow this general course:

Starting with the first cog symbol in the Inventory File, quantities of interest are computed by linear interpolation between tabled values. The weighted sum of referrals and replenishment requisitions leaving each echelon is used to estimate the throughput time in the echelon and the workload entering the succeeding echelon. From average availability an throughput time distribution the average and distribution of response time is computed.

Other quantities of interest, such as total echelon inventory and workload and incremental cost of improved performance, are computed and displayed at the user's option.

Incremental costs are handled in two ways: (a) as the specific amounts of additional salaries, capital equipment purchases, and other costs that must be incurred to increase the level of service above that in the base (i.e., current) case or (b) as the difference in marginal cost of holding inventory, carrying items, issuing and receiving material, and referring requisitions between the case under study and a base case.

3. Outputs

A sample of each of the four sections of output is contained in Figure V-5. The first part simply describes the inventory cases used in the particular run and the structure of the remainder of the report. Part 2 supplies the average requisition response time of these commodities. The third and fourth parts, both optional, display the difference in resource requirements and in marginal operating costs between a base case and the case under consideration.

F. Converter

The last in the chain of 5 computer programs developed for S^4 is the Converter, whose basic function is to convert requisition response time distributions into supply response time distributions and estimates of equipment operational availability. The program runs and produces results by equipment for as many equipments as are included in the data base.

1. Inputs

The information required to operate the Converter comes from three sources:

° The Synthesizer, whose principal product, distribution of requisition response time for each of 15 cog symbols, is a major input to the Converter. The requisition response time for part-numbered requisitions is computed manually and fed in standard format to the Converter

° A maintenance profile for each equipment of interest. A special program designed for the study analyzes each equipment's maintenance history from the 3-M Data Collection System and computes frequency distributions of (a) number of parts required per maintenance action and

SYNTHESIZER REPORT FORMAT

SYNTHESIZER REPORT NUMBER ____________________
SHIPS SUPPLY SUPPORT STUDY ____________________
FLEET: 6____________ DATE: ____________
REQUESTED BY: ____________________
PART I: REPORT DESCRIPTION

A. INVENTORY CASES USED

		1H	2H	1A 9Z
SHIP CASE	CASE			
	VARIB			
	VALUE			
MLSF	CASE			
	VARIB			
	VALUE			
SCREEN	CASE			
	VARIB			
	VALUE			
STK PT	CASE			
	VARIB			
	VALUE			
ICP	CASE			
	VARIB			
	VALUE			

B. PROCESSING LEGS USED

LEG NR. WORKLOAD (% OF BASE)

C. THIS REPORT INCLUDES

PART 2: RESPONSE TIME REPORT
PART 3: INCREMENTAL RESOURCE ANALYSIS
PART 4: RESOURCE, WORKLOAD, AND PERFORMANCE BY ECHELON

THIS REPORT ASSUMES ABSOLUTE/PROPORTIONAL CHANGE IN WORKLOAD

FIGURE V-5

SYNTHESIZER REPORT FORMAT (CONT.)

SYNTHESIZER REPORT NUMBER ____________
SHIPS SUPPLY SUPPORT STUDY ____________
FLEET: 6 ____________ DATE: ____________
PART II: REQUISITION RESPONSE TIME ____________

COG SYMBOL	AVERAGE DAYS	PROBABILITY OF FILLING REQUISITION IN X DAYS OR LESS
		1 2 3 ....360 OVER 360
SHIPS PARTS - HM&E		
1H		
2H		
SHIPS PARTS - ORDNANCE		
1N		
2A		
4A		
2U		
ELECTRONICS SUPPLY OFFICE		
1N		
2N		
4N		
2G		
4G		
DEFENSE SUPPLY AGENCY		
9C		
9G		
9N		
9Z		

FIGURE V-5

SYNTHESIZER REPORT FORMAT (CONT.)

SYNTHESIZER REPORT NUMBER ____________
SHIPS SUPPLY SUPPORT STUDY ____________
FLEET: 6 ____________ DATE: ____________
PART III: INCREMENTAL RESOURCE ANALYSIS
SECTION A: CHANGE IN INVENTORY ($000)

COG	SHIP	MLSF	STOCK POINT	ICP
1H				
.				
.				
.				
9Z				
TOTAL				

SECTION B: CHANGE IN OTHER RESOURCES ($000)

APPN	SHIP	MLSF	SCREEN	STOCK POINT	ICP
O&MN-SALARY					
O&M - OTHER					
OPN					
RDT&E					
OTHER					
TOTAL (AN)					
TOTAL (OT)					

("AN" FOLLOWING VALUE MEANS ANNUAL COST: "OT" MEANS ONE TIME COST)

FIGURE V-5

SYNTHESIZER REPORT FORMAT (CONT.)

SYNTHESIZER REPORT NUMBER ________________
SHIPS SUPPLY SUPPORT STUDY ________________
FLEET: 6 __________ DATE: __________
PART IV: INVENTORY, WORKLOAD, AND PERFORMANCE

COG SYM	TYPE	INVENTORY@ $000	$000 PER YEAR DEMANDS	$000 PER YEAR ORDERS	ITEMS @ CARRIED	REC'D*	ISSUED@	REF'D@	REPLEN	GROSS* AVAIL	CUMUL* AVAIL	CONTR* TO R
TOTAL												
MARG $												

*Screening echelon displays only this information opposite "TOTAL" and displays nothing opposite "MARG $"

@Marginal dollar costs are shown opposite "MARG $" only under this heading.

FIGURE V-5

(b) relative appearance of cog symbols (including part-numbered items) in maintenance actions. Figure V-6 illustrates a typical maintenance profile.

° A special NAVSHIPS program which computes mean time between failures (MTBF) and mean time to repair (MTTR) for each equipment. However, these values can be supplied from any source.

The user may modify any of the three frequency distributions - requisition response time, parts per repair, or cog symbols per repair. He also selects the equipments in the data base for analysis and the number of maintenance actions to be simulated per equipment.

2. Procedure

Essentially, the Converter performs a Monte Carlo simulation of up to 1000 possible corrective maintenance actions on a particular equipment, employing these major steps:

a. Read in an equipment record

b. Generate a random number to determine the number of parts required in the simulated maintenance. The number of parts to be used depends on the random number generated and the frequency distribution of parts contained in the maintenance profile.

c. For each of the parts to be used in the repair, generate another random number to decide the cog symbol of the part needing replacement. Note that the cog symbol selected is also a function of the data in the maintenance profile and that a single cog symbol may be selected more than once.

d. For each part selected, generate a third random number to decide when the part will be received by the mechanic. The time selected will depend on the response time frequency distribution calculated in the Synthesizer.

e. If no parts are required the supply response time is zero. If 1 part is required, the response time is simply the time selected in d above.

f. If 2 or more parts are required, calculate times as in d above for all but the last part and retain the largest number.

g. Before the time to requisition the last part is computed, generate an additional random number to decide whether this corrective maintenance action will be subject to serial requisitioning -- the requisitioning of needed parts in 2 batches rather than a single batch at the time of initial failure diagnosis. If serial requisitioning is to occur, then the supply response time is the <u>sum</u> of the time selected for the last part and the result of step f. If serial requisitioning

MAINTENANCE ACTION PROFILE

APL 570366300 NOMEN AN/SPS-10F RADAR SET
MTBF = 418.00 hrs. MTTR = 3.50 hrs.

PARTS PER MAINT ACTION DISTRIBUTION

NR PARTS	NR ACTIONS	FREQ(%)
0	277	0.3700
1	245	0.3280
2	89	0.1190
3	42	0.0560
4	29	0.0390
5	18	0.0240
6	16	0.0210
7	11	0.0150
8	3	0.0040
9	3	0.0040
10 or more	15	0.0200

COG USAGE DISTRIBUTION

COG	TIMES USED	FREQ(%)
1A	0	0.0000
1H	5	0.0040
1N	27	0.0214
2A	0	0.0000
2H	1	0.0008
2N	9	0.0072
4G	0	0.0000
4N	0	0.0000
9C	8	0.0063
9G	69	0.0549
9N	1067	0.8509
9Q	1	0.0008
9Z	62	0.0493
PN	6	0.0044
*Other	1	

*Not considered by Converter

FIGURE V-6

CONVERTER OUTPUT

570366300 AN/SPS-10F RADAR SET MTBF = 418.00 MTTR = 3.50

S(DAYS)	FREQ	S(DAYS)	FREQ	S(DAYS)	FREQ
0	.3640	17	.0150	46-50	.0040
1	.2480	18	.0140	51-55	.0110
2	.0060	19	.0110	56-60	.0050
3	.0160	20	.0220	61-75	.0040
4	.0050	21	.0100	76-90	.0090
5	.0150	22	.0080	91-105	.0010
6	.0080	23	.0130	106-120	.
7	.0170	24	.0110	121-135	.
8	.0080	25	.0130	136-150	.
9	.0080	26	.0070	151-180	.0010
10	.0110	27	.0060	181-210	.0020
11	.0110	28	.0070	211-240	.
12	.0150	29	.0070	241-270	.
13	.0080	30	.0030	271-300	.
14	.0100	31-35	.0090	301-330	.
15	.0130	36-40	.0160	331-360	.
16	.0120	41-45	.0070	360	.

MSRT = 8.86 DAYS VARIANCE = 76.93

AVG PARTS PER MAINT ACTION = 1.54

OPERATIONAL AVAILABILITY A(0) = 0.6592

FIRST PARTIAL DERIVATIVE DA/DS = -0.0250
570366300 HAS BEEN SIMULATED.

FIGURE V-7

is not to occur, the supply response time for the repair is the larger of the requisition time for the last part or the result of step f.

h. When the desired number of maintenance actions has been simulated, compute the mean supply response time (MSRT) and its variance, operational availability, and the rate of change of operational availability with respect to MSRT.

i. Repeat above steps for next equipment.

3. Outputs

The outputs of the Converter program are, for each equipment:

° The nomenclature and component identification number (CID) of the equipment.

° The distribution of supply response time.

° The mean supply response time and its variance.

° The mean time between failure (MTBF), the mean time to repair (MTTR), and the mean administrative delay time (MADT).

° The equipment's operational availability and the first derivative with respect to MSRT.

Output for a typical equipment is displayed in Figure V-7.

VI. ANALYSES AND EXPERIMENTS

This Chapter reports the results of two parametric analyses and several experiments conducted during the course of S^4. The analyses and experiments were performed to:

demonstrate the kinds of problems that can be illuminated with the tools developed during S^4.

supply answers raised by potential users of S^4 computer programs.

develop a basis for further detailed analyses in specific areas of supply support.

All of the analyses and experiments have been run on early versions of the Inventory Simulators and Synthesizer and have relied on observed, vice computed, values of throughput time. This fact detracts neither from the demonstration function no from the ability to indicate areas needing further study.

A. Parametric Analyses

1. Analysis of Requisition Response Time

Estimates of throughput time and of gross availability, observed or constructed as described in Chapter V, were supplied to the Synthesizer for the computation and analysis of requisition response time. The purposes of the analysis were to:

- provide benchmark estimates of requisition response time for comparison with values from other sources.

- compute the direct contribution of each echelon to the satisfaction of end-use requisitions, in terms of both probability of satisfaction and time to satisfy.

- estimate of effect on requisition response time of marginal changes in availability and throughput time as a basis of further detailed investigation.

The parametric analysis provided a wealth of detailed information, summarized in the following paragraphs.

Table VI-1 contains, for each cog symbol, the requisition response time computed by the synthesizer and the unweighted average decrease in requisition response time resulting from (a) a one percentage point increase in gross supply availability at an echelon

AVERAGE AND MARGINAL CHANGES

IN REQUISITION RESPONSE TIME

Based on Observed Availability and Throughput Time

COG SYMBOL	REQUISITION RESPONSE TIME	IMPROVEMENT IN RESPONSE TIME DUE TO Raising Availability 1 Percentage Point	Decreasing Processing Time 1 Day
1A	19.56 days	0.22 days	0.10 days
1H	10.23	0.18	0.07
1N	8.51	0.10	0.06
2A	19.31	0.20	0.08
2G	17.65	0.23	0.09
2H	23.68	0.32	0.08
2N	33.02	0.43	0.08
2U	13.69	0.20	0.06
4A	12.12	0.15	0.10
4G	13.33	0.19	0.08
4N	15.43	0.19	0.10
9C	9.85	0.13	0.07
9G	6.11	0.07	0.06
9N	4.77	0.07	0.04
9Z	6.19	0.06	0.06

TABLE VI-1

and (b) a one day decrease in throughput time at any echelon. An identical <u>increase</u> in response time would result from the same changes in the opposite direction. The unweighted averages are the sums of the marginal improvements at each echelon divided by the number of echelons. As such they cannot be manipulated mathematically but do give a general indication of the commodities in which a given increase in availability or decrease in throughput time would have the most benefit.

The table suggests that, generally speaking, DSA managed items have the shortest response times, APA items the longest, and NSA items intermediate response times. The table also shows that there is a close correlation between response time and the improvement in response time resulting from a one percentage point increase in availability.

On the other hand, reductions in throughput time have, on the average, about the same effect on response time, regardless of the cog symbol. Such is not the case for improvements in througnput time for all cogs in an echelon, as Table VI-2 demonstrates.

AVERAGE DECREASE IN REQUISITION RESPONSE TIME

DUE TO ONE DAY DECREASE IN THROUGHPUT TIME

ECHELON WITH DECREASED THROUGHPUT TIME	IMPROVEMENT IN RESPONSE TIME
Shipboard	Negligible
MLSF	0.19 days
Screening	0.02
Stock Point	0.15
ICP Referral	0.09
ICP Backorder	0.03
ICP Spot Buy	0.01

TABLE VI-2

Improvements in processing time at the mobile logistic support force and stock point echelons offer the greatest benefits to response time.

The sort of information developed during the parametric analysis is illustrated in Table VI-3, which gives detailed data for the cog symbols with the shortest and the longest response time. It shows that at least half the mechanic's requirements are satisfied within a few hours and that 75% to 95% are supplied in 30 days. It also reveals the effect of shipboard availability and long procurement leadtimes on overall response time.

2. Analysis of Operational Availability

Approximately 275 equipments were selected for an assessment of the effect on operational availability of changing supply response time. Criteria for equipment selection were:

- The equipment appears on an OPNAV listing of essential weapons dated 27 April 1971.

- The equipment is one of the top 25 composite 3M/CASREPT equipments in terms of failures appearing in either the October 1971 or January 1972 edition of NAVSHIPS Problem Detection Report.

- The generic equipment is indicated in the 3-M Information System Equipment Identification Code Master Index (MSO 4790.E2579) of October 1971 as requiring failed part reporting and the specific equipment was (a) installed in large quantities in the fleet and (b) involved in at least one casualty in the year ending 30 September 1971 as indicated in CASREPT HM&E Statistics by CID

ECHELON ANALYSIS OF REQUISITION RESPONSE TIME

ECHELON	CUMULATIVE AVAILABILITY	THROUGHPUT TIME	CONTRIBUTION TO RESPONSE TIME	IMPROVEMENT IN RESPONSE TIME DUE TO 1% Higher Availability	IMPROVEMENT IN RESPONSE TIME DUE TO 1 Day Shorter Throughput Time
2N - Ship Electronic Components Managed by ESO					
Ship	49.1%	0.236 days	0.11 days	0.66 days	Negligible
MLSF	49.1	No Stock Carried in MLSF			
Screen	52.2	12.0	0.37	0.44	0.03 days
Stk. Pt.	72.1	28.2	5.6	0.32	0.20
ICP Refer.	87.9	47.1	7.4		0.16
ICP B.O.	98.1	149.5	15.2	0.30	0.10
ICP S.B.	100.0	225.6	4.3		0.02
		TOTAL	33.02 Days		
9N - Electronic Parts Managed by DSA					
Ship	75.1%	0.25 days	0.18	0.18 days	----
MLSF	88.8	8.0	1.09	0.07	0.14 days
Screen	90.3	12.0	0.18	0.06	0.02
Stk. Pt.	96.5	31.4	1.95	0.01	0.06
ICP Refer.	99.8	35.4	1.18		0.03
ICP B.O.	100.0	84.9	0.17	0.01	0.01
ICP S.B.	100.0				
		TOTAL	4.77 Days		

TABLE VI-3

Number, (RCS SUP 440.27-75) of 30 November 1971.

Operational availability is, by definition, the percentage of total time in which an equipment is capable of being operated. This does not mean that it is in fact being operated throughout this percentage of time, but only that it is functional should its operation be required. A_o may also be defined as the ratio of uptime to total time. Symbolically,

$$A_o = \frac{\text{Uptime}}{\text{Total Time}} = \frac{MTBF}{MTBF + MADT + MTTR + MSRT} \quad (1)$$

where: MTBF = mean time between failure
MADT = mean administrative delay time
MTTR = mean time to repair (active repair time)
MSRT = mean supply response time

The rate of change of A_o with respect to MSRT is given by the first partial derivative.

$$\frac{\partial A_o}{\partial(MSRT)} = -\frac{MTBF}{(MTBF + MADT + MTTR + MSRT)^2} \quad (2)$$

Given values for the variables MTBF, MADT, and MTTR for each equipment, one can then vary MSRT over some plausible range to note the effect on A_o. Obviously, A_o varies inversely with MSRT; however, a graph of A_o versus MSRT can point out the impact on availability of reductions in MSRT. Such a graph can also isolate an equipment whose reliability is either so good or so bad as to rule out improvement of MSRT as a means to improve A_o significantly.

MADT is not available on an equipment basis. The 3-M system does classify deferred maintenance actions by major headings, some of which are normally considered to be administrative delays (deferred for outside assistance or deferred due to ships operations), but the elapsed times on such maintenance actions when completed consist of administrative delay time, repair time, and mean supply response time, i.e., the entire downtime. Thus, it is not possible to measure MADT directly from the available data. As a result, equations (1) and (2) should more properly be written as follows:

$$A_o = \frac{MTBF}{MTBF + MTTR + MSRT^*} \quad (3)$$

$$\frac{\partial A_o}{\partial(MSRT^*)} = -\frac{MTBF}{(MTBF + MTTR + MSRT^*)^2} \quad (4)$$

where: MSRT* = MSRT + MADT

MSO is currently involved in a research project involving the NAVSHIPS MDCS (Maintenance Data Collection Subsystem), a package of experimental computer programs developed for NAVSHIPS by Computer Sciences Corporation. MSO is tasked with conversion of these experimental programs to operational programs which make use of 3-M data. At the inception of the S^4 project, there existed no technique to compute the MTBF and MTTR vital to MSO's participation in the project; however, the NAVSHIPS MDCS includes a computational module capable of computing MTBF and MTTR. It was determined to make use of this program even with the realization that no ordnance equipments could be input.

The 120 NAVSHIPS equipments for which equipment identification codes (EICs) could be found were input to the NAVSHIPS MCDS program to obtain their respective MTBF and MTTR in hours. The output listing, however, contained only 77 entries; the primary cause of incompleteness was the fact that the integral cross-reference list which allows matching between EIC and component identification code and ship had not been kept current. Of the 77 output entries, only 38 had both required pieces of data. Values of MTBF were missing in those cases where neither steaming hour nor operating hour information had been recorded.

Thus, of the original 275 equipments, only 38 had the necessary data for the parametric analysis. For these, equations (3) and (4) were evaluated for values for MSRT from 0 to 120 days and the curves plotted directly on a Cal-Comp 765 Digital Plotter at MSO, with results exemplified by Figures VI-1, VI2, and VI-3.

A_0 is as much a function of engineering reliability as it is of MSRT. Thus, there exist two different reasons for the inability of MSRT to significantly improve A_0: either the equipment hardly ever fails (as reflected by a very large MTBF) or it hardly ever works (as reflected by a very low MTBF). In either case the significant improvement of A_0 by supply means alone is hopeless - in the first case (high MTBF), happily unnecessary, and in the second case (low MTBF) unhappily true. For this reason, equipments can be segraged into three groups with respect to MSRT: (1) those equipments for which A_0 can be significantly improved by effecting lower MSRT (typified by Figure VI-1), (2) those equipments whose reliability is so high as to insure very high A_0 regardless of MSRT (See Figure VI-2); and those equipments (of which Figure VI-3 is an example) with such a short average time between failure that even reduction of MSRT to a scarcely credible 5 days produces an A_0 of only about .50 to .60. The distribution of analyzed equipments is about equal among these three groups.

B. Completed Experiments

At the S^4 Users Conference held at the Fleet Material Support

OPERATIONAL AVAILABILITY
OF AN/WRT 2 TRANSMITTING SET, RADIO
MTBF-2126.0 HRS.
MTTR-10.0 HRS.

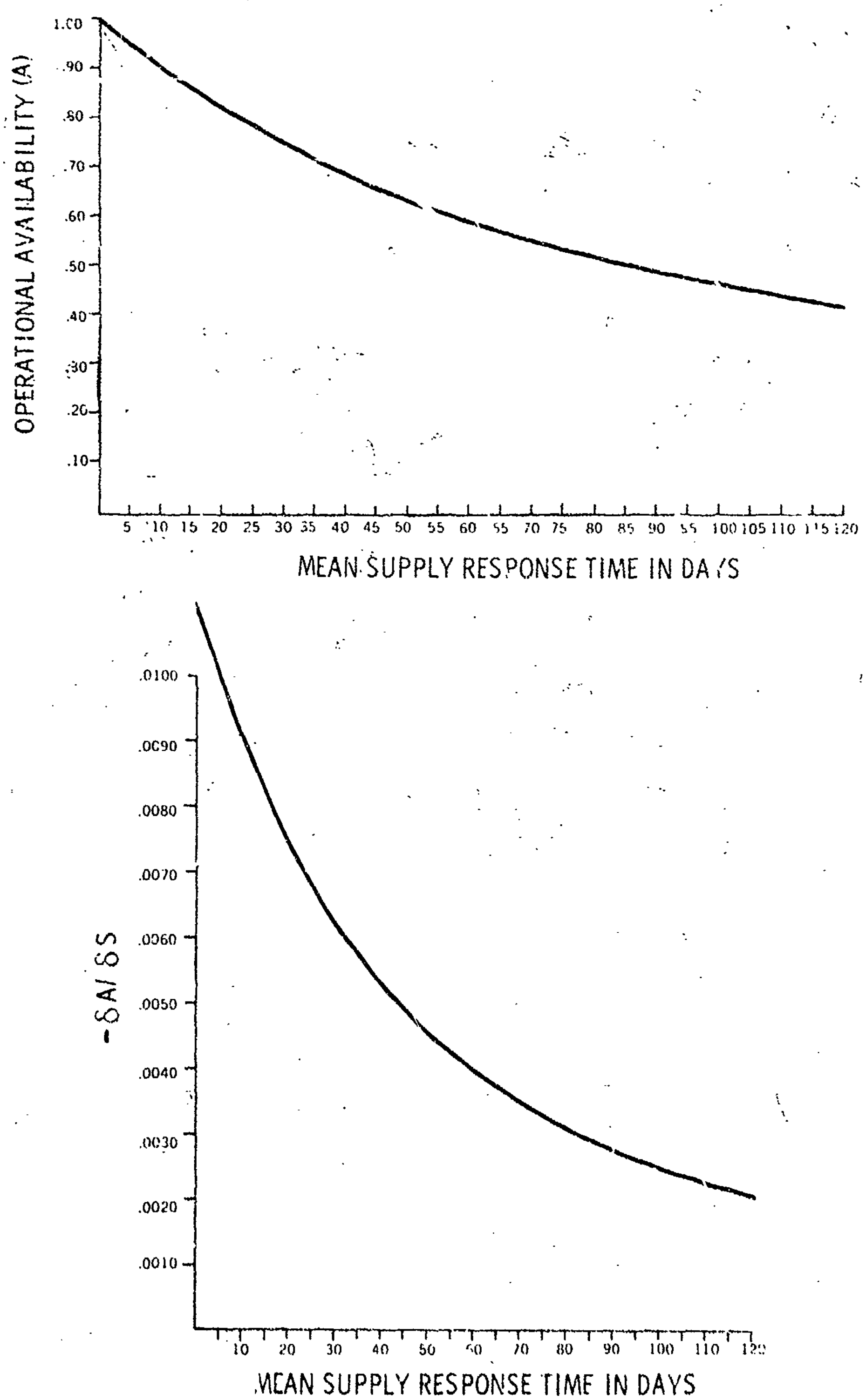
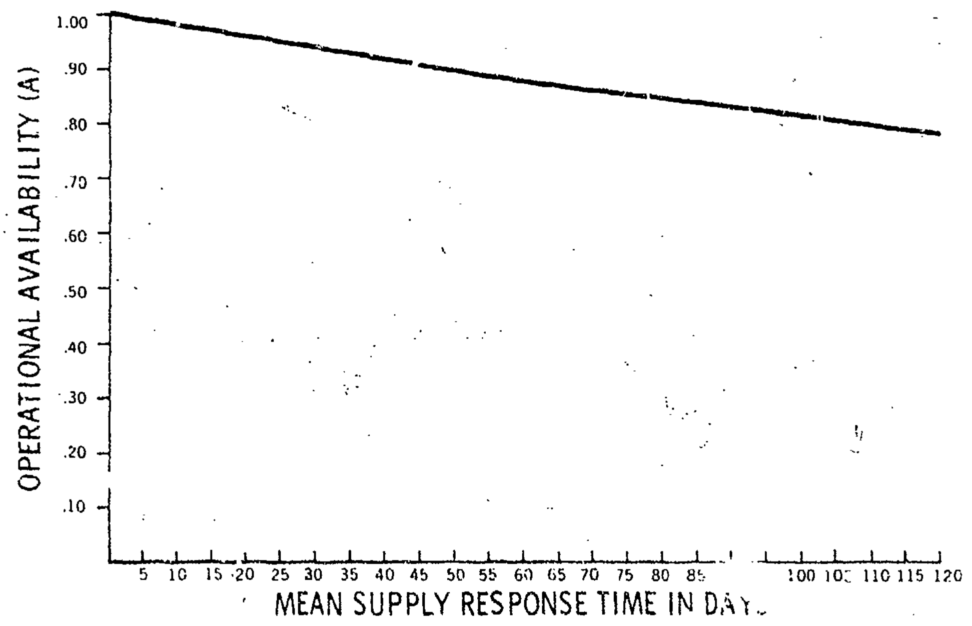


FIGURE VI-1

OPERATIONAL AVAILABILITY
OF AN/WRC 1 TRANSCEIVER, RADIO
MTBF-10478.0 HRS
MTTR-6.3 HRS.



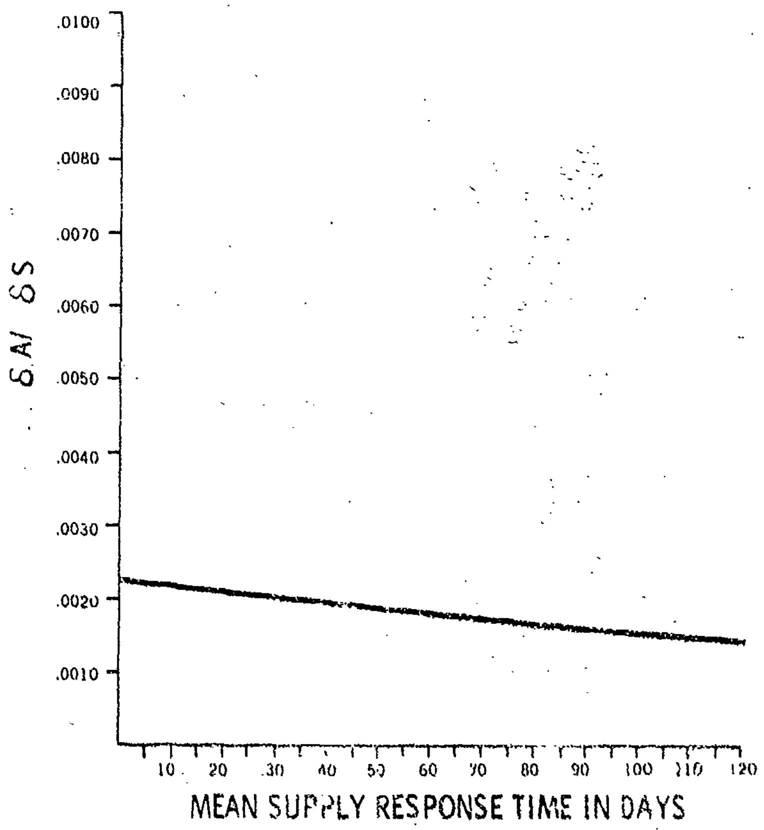
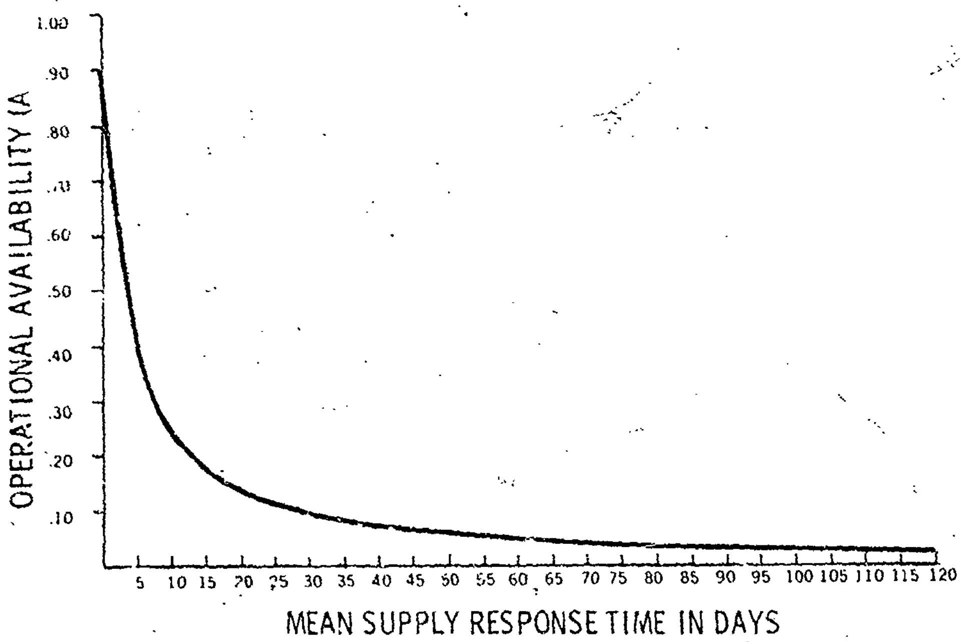


FIGURE VI 2

OPERATIONAL AVAILABILITY
OF AN/ULQ 6A REPEATOR, COUNTERMEASURES, ECM, PULSE
MTBF-79.0 HRS.
MTTR-9.9 HRS.



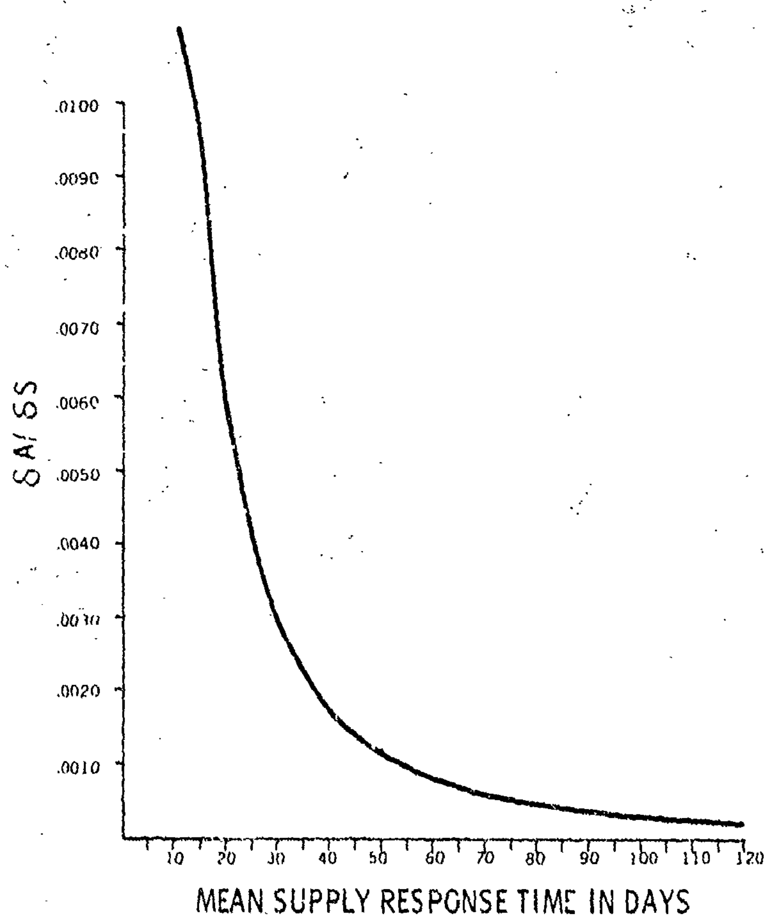


FIGURE VI-3

Office on 7 February 1972, many proposals were made concerning the design and capability of the S[illegible] programs and experiments that might be run on completed programs. The results of running many of these experiments as well as those suggested subsequent to the conference are described in this section. A few experiments were not completed for lack of time; these are listed in Section C.

Experiment 1 - Eliminate all items from COSALs that appear solely because they are technical override (TOR) items.

The structure of the FLSIP COSAL model allows items to be included on the COSAL under several criteria:

o Demand. An item has a predicted shipboard demand of one or more units in 90 days. Depth is determined by demand rate.

o Insurance. An item has a predicted shipboard demand between 0.15 and 4 units per year. Depth is 1 minimum replacement unit.

o Override. An item is identified as being required in the execution of a preventive maintenance plan (i.e., a PMR) or an item has been identified by a hardware systems command to be included in the on-board allowance (i.e., a TOR). Depth is 1 minimum replacement unit. Only the latter group of the override items is the subject of this experiment.

The data used in the analysis are applicable to six different ships representing a diversity of ship types. The statistics displayed in Table VI-4 represent summary data applicable to the current FLSIP COSAL which includes TOR items. The availability measure represents gross requisition effectiveness resulting from simulating the six ships using actual usage data as reported to the 3-M system.

SUMMARY STATISTICS FOR THE BASIC FLSIP COSAL

SHIP	ITEMS ON COSAL	DOLLAR VALUE OF INVENTORY ($000)	SIMULATED AVAILABILITY (%)*
AOE-3	8,505	$ 373	48%
CG-10	30,123	2,408	55
DD-933	12,993	000	45
DDG-35	18,964	1,294	52
DLG-15	21,274	1,350	56
LPA-249	11,506	304	49

TABLE VI-4

*Based on all demands not just those reported as relating to specific equipment.

The first step in the experiment was to remove all items included in the COSAL solely because they were TOR items. As Table VI-5 indicates, a few items designated as TOR by a hardware systems command also qualify as demand or insurance based items.

RESULTS OF ELIMINATING TOR QUALIFICATION

SHIP	TOR CANDIDATES	MIGRATION TOR TO DEMAND	MIGRATION TOR TO INSURANCE	TOR ELIMINATED	PERCENT ELIMINATED
AOF-3	154	1	39	114	74%
CG-10	5,633	23	97	5,513	98
DD-933	2,201	17	55	2,129	97
DDG-35	2,576	20	82	2,474	96
DLG-16	3,171	13	99	3,059	96
LPA-249	1,361	2	17	1,342	99

TABLE VI-5

Tables VI-6 and VI-7 show the consequences of removing pure TOR items.

Table VI-6 indicates that the dollar value reduction across all ships in the sample was approximately 18%, but that the reduction per ship ranged from 2 to 23 percent. It also shows that the largest reductions occurred on ships with missile systems, (i.e., CG, DDG, DLG). If one considers the cognizance of material one finds that large reductions occurred in N and A cog. This predominance of electronics and ordnance material indicates that the policy of adding TORs to insure that Surface Missile Systems repair parts are included in the FLSIP COSAL is being followed.

Table VI-7 reveals that the reduction in gross availability and the increase in requisition response time are by no means commensurate with inventory reductions.

The way to achieve the savings inferred by this experiment would be (1) to fail to replenish a TOR item as soon as it is issued from the ship's storeroom and to delay ordering until another end-use requirement arises for the part and (2) to exclude TOR items from the provisioning of new equipments. (Removal of TOR items physically stocked aboard ship is <u>not</u> efficient because it incurs transportation and material handling costs now and requisitioning delays in the future, both of which would have been avoided if the material had remained aboard ship.) Although there are no firm statistics available on this point, it is reasonable to assume that, because of equipment redesign and replacement, new and different TOR items would be provisioned over the coming 10 years to replace all those

REDUCTION IN SHIPBOARD INVENTORY VALUE

COG	AOE 3	CG 10	DD 933	DDG 35	DLG 16	LPA 249	IN PERCENT
	IN THOUSANDS OF DOLLARS						
1A	-	2	1	86	1	-	23%
1H	3	3	6	3	8	1	5
1N	-	184	14	72	153	10	43
2A	-	14	3	30	8	-	17
2H	7	5	5	--	-	1	8
2N	-	103	1	21	92	-	23
2U	-	2	-	2	2	-	3
4G	-	4	4	3	5	6	13
4N	-	67	6	10	16	5	10
9C	1	2	2	2	2	-	3
9G	-	8	4	4	3	-	12
9N	-	52	13	19	26	9	18
9Z	-	2	-	1	-	10	10
TOTAL	11	448	59	253	316	42	
% REDUC.	2%	18	16	19	23	13	18

TABLE VI-6

CHANGE IN GROSS AVAILABILITY AND RESPONSE TIME

COG	AOE 3	CG 10	DD 933	DDG 35	DLG 16	LPA 249	OVERALL AVERAGE	RESPONSE TIME INCREASE
	GROSS AVAILABILITY REDUCTION							
1A	-	1%	-	2%	1%	-	.6%	0.2 da
1H	-	-	-	-	-	-	0	0.0
1N	-	6	2	11	3	5	4.5	0.9
2A	-	2	-	-	-	-	.3	0.1
2H	-	-	-	2	6	-	1.3	0.6
2N	-	7	-	16	17	9	8.1	5.3
2U	-	-	-	-	-	-	0	0.0
4G	-	2	11	-	6	3	3.6	0.9
4N	-	-	4	5	-	-	1.5	0.5
9C	-	-	1	-	-	2	.5	0.1
9G	-	1	1	1	5	-	1.3	0.2
9N	-	-	1	1	-	1	.5	0.1
9Z	-	4	-	1	1	-	1.0	0.2
ALL COGS	0	1	1	1	1	1	1	0.3

TABLE VI-7

now aboard ship, if the TOR policy did not change. It it did change then an average of $188,000 would be saved per ship over the among 10 years, as indicated in Tabel VI-6. Of course, any general rule must have exceptions and it is certain that some TOR items would, for valid reasons, be provisioned in the future. Assume, in fact, that 50% of those provisioned under previous rules will continue to be provisioned. Then the gross annual dollar savings for the 60 ships in the Sixth Fleet is: $188,000 X 0.5 X 0.1 X 60 or $564,000.

Offsetting this gross saving is the possibility of additional CASREPT requisitions to be processed in the Sixth Fleet. Table VI-7 suggests that absence of TOR items will increase requisitions leaving the ship by about 2 percent (say from between 40 and 60 percent to between 41 and 61 percent.) Assuming CASREPT requisitions increase in proportion and assuming the MATCONOFF cost per requisition is $8.68, the annual increase in CASREPT requisition screening cost is less than $1000.

Against the net dollar saving of $563,000 per annum is a malificence (or negative benefit) of 0.15 days increase in response time for every part needed by a mechanic if only half the TOR items are removed. Of course, this response time increase could be mitigated by stocking one unit of each TOR item on the AFS or, at even less cost, at NSC Norfolk. Time did not permit analysis of the cost or reduced malificence of either of these approaches.

Experiment 4 - This experiment assumes that the MATCONOFF screening function terminates, thus requiring the 5,700 high priority requisitions now filled by Sixth Fleet ships annually to be referred to NSC Norfolk. Under one assumption, NSC Norfolk has a range and depth of stock at least equal to that of all Sixth Fleet ships combined. Under a more restrictive assumption, Norfolk would provide no higher an availability, in percentage terms, than it now does. These two assumptions form the basis for the minimum and maximum delays, respectively, shown in the third and fourth columns of Table VI-8. The average delays over all commodities are 0.27 days and 0.45 days.

The specified delay is the average additional delay spread over all end-use requisitions, even those satisfied from shipboard stock. The average delay ranges from 0.11 to 1.72 days. In fact, only a portion of the requirements would be delayed, inasmuch as (a) most requirements are satisfied aboard ship or from the AFS and (b) others would not have been satisfied by screening in any event.

Those requisitions actually delayed in filling by the absence of the MATCONOFF screening are delayed a considerable time as the

ELIMINATION OF MATCONOFF SCREENING OF HIGH-PRIORITY REQUISITIONS

COG SYMBOL	CURRENT RESPONSE TIME	AVERAGE DELAY TO ALL END-USE REQUISITIONS Minimum	Maximum	MINIMUM DELAY TO HIGH PRIORITY REQUISITIONS
1A	19.56 da.	0.32 da.	0.68 da.	13.4 da.
1H	10.23	0.39	0.82	14.1
1N	8.51	0.11	0.57	19.7
2A	19.31	0.27	0.68	14.2
2G	17.65	0.24	0.76	7.3
2H	23.68	0.20	1.53	4.8
2N	33.02	0.57	1.72	16.2
2U	13.69	0.22	0.62	10.4
4A	12.12	0.07	0.26	2.3
4G	13.33	0.68	1.16	19.0
4N	15.42	0.16	0.74	3.4
9C	9.85	0.35	0.61	18.3
9G	6.11	0.13	0.16	20.3
9N	4.77	0.29	0.31	19.4
9Z	6.18	0.17	0.19	14.7

TABLE VI-8

last column in Table VI-8 indicates. By finding a source of material within the Mediterranean for over 60% of the requests sent to it, the MATCONOFF avoids at least 105,000 requisition days of delay annually on requisitions that are presumably associated with ships' casualties. It does this at a direct cost of less than $50,000 per year.

Experiment 5 - This experiment addresses the exclusion of NSC Norfolk from support of the Sixth Fleet for DSA Material. There are two conditions under which this could occur. In the first situation, the stock now at Norfolk would be transferred to one or more DSA prime depots. As a result, the cumulative gross availability after requisitions have passed through the prime depot echelon would by identical to its current value. Requisition delays under this assumption are shown in the upper half of Table VI-9, under the heading "Minimum Delay". The table shows the average delay to all end-use requisitions, the percent of total requisitions actually delayed, and the average delay to these requisitions. (The delays in the last column of Table VI-9 are not incompatible with the data in Figure V-4 which suggest that requisitions sent directly to a DSC would take 3 to 10 days longer to fill than ones filled at NSC, Norfolk.) Note that "all" requisitions include those satisfied aboard ship; for DSA cogs, 1/2 to 2/3 of the demands have

ELIMINATION OF NSC NORFOLK AS END-USE REQUISITION SOURCE FOR DSA MATERIAL

COG SYMBOL	CURRENT RESPONSE TIME	AVERAGE DELAY TO ALL REQUISITIONS	REQUESTS DELAYED	DURATION OF DELAY
A. Minimum Delay				
9C	9.85 days	0.69 days	9.1%	7.60 days
9G	6.11	0.44	7.8	5.68
9N	4.77	0.25	6.2	4.00
9Z	6.18	0.54	10.4	5.23
B. Maximum Delay				
9C	9.85 days	2.20	19.8%	11.11 days
9G	6.11	0.97	11.7	8.29
9N	4.77	0.44	9.7	4.54
9Z	6.18	0.80	14.6	5.48

TABLE VI-9

historically been satisfied aboard ship.

Under the second possible situation either (a) the DSA stock Norfolk now carries would simply disappear or (b) Sixth Fleet end-use requisitions would bypass Norfolk and go directly to DSA for processing. In either event, the availabilities of the various DSA echelons are assumed to remain constant. The consequences of these assumptions are contained in the lower half of Table VI-9.

With respect to cost reductions resulting from removing NSC Norfolk from the chain of supply, three situations are possible:

o If the DSA inventory is transferred to DSA depots, item management costs and receipt costs at Norfolk will be avoided, saving $1,185,000 per year. This saving may be offset by possibly higher unit issuing costs at DSA and increased transportation costs.* Furthermore, Second Fleet and Shore Establishment customers of Norfolk may suffer greater degradation in service than Sixth Fleet users.

*See: A Comparison of the Costs and Service Levels Associated with Two Alternative Retail Inventory Distribution Concepts: Final Report; Control Analysis Corp.; Palo Alto, California, February 1973 o If the Norfolk inventory is eliminated by attrition, then a net of $8 million in reduced holding costs can be added to the above. The comments given above about reduced customer service apply.

o If only Sixth Fleet requisitions are sent directly to DSA, the maximum savings are $33,000 annually, reduced by any possible increases in transportation costs and requisition processing costs at DSA.

Construction of the above costs is shown in Table VI-10.

Experiment 6 - In this experiment the effects of reduction in communication, processing and delivery times below the wholesale echelon are investigated. The results are displayed in Table VI-11. Clearly, one day saved in communication to or shipment from CONUS promises greater benefits than one day faster delivery from the AFS because the CONUS echelons collectively supply more material than does the AFS alone. Furthermore, there are more alternatives available when trying to reduce CONUS throughput time than AFS time. In achieving response time savings one would want to reduce that segment of requisition/material processing which produces a day's saving at least cost.

Experiment 7 - The objective of this experiment is to reduce inventory investment at the wholesale level by reducing the range of items carried while at the same time minimizing the impact of range reduction on gross availability and response time. This is accomplished* by:

o Computing for each item on the stock list the probability that one or more demands will occur during a leadtime. Mathematically this is $\left(1 - \frac{1}{2.781^{\text{Lead Time Demand}}}\right)$

o Divide the above by the unit price of the item to determine the probability of leadtime demand per dollar invested in the item.

o If the above quotient is greater than an arbitrary number, X, keep the item on the stock list. If it is not, remove the item.

As X increases, fewer and fewer items meet the requirement and the stock list shrinks. Because the Navy does not now apply such a

*The rule is taken from Methodology for Determining Initial Provisioning of Insurance Type Items; Robert W. Burton and Stratton C. Jaquette; Decision Studies Group, November 1971

COST CONSEQUENCES OF CHANGING

NSC NORFOLK'S SUPPORT MISSION

COG SYMBOL	ITEMS STOCKED	NSC NORFOLK INVENTORY 1/ ($000)	INCOMING REQUISITIONS NOW SATISFIED PER MONTH Total	Sixth Fleet	REPLENISHMENT ACTIONS PER MONTH 2/
9C/AX	6,742	18,315	13,595	446	1972
9G/CX	36,585	14,929	13,060	397	1838
9N/TX	137,969	31,101	38,938	889	5955
9Z/KZ	67,655	3,802	27,857	651	2493
TOTAL	248,951	68,147	93,450	2,383	12,258
Annual $ Marginal Cost 3/ ($000)	197	$ 9,200	$ 1,312	$ 33	$ 988

1/ As of 31 December 1971.
2/ Includes MTIS receipts.
3/ See Section III-B for unit cost estimates.

TABLE VI-10

EFFECTS OF REDUCED COMMUNICATION,

PROCESSING, AND TRANSPORTATION TIME

COG SYMBOL	CURRENT RESPONSE TIME	BENEFIT OF ONE DAY SAVED On All Requisitions Referred to CONUS	On Delivery From AFS
1A	19.56 days	0.46 days	0.14 days
1H	10.23	0.18	0.22
1N	8.51	0.19	0.19
2A	19.31	0.40	0.09
2G	17.65	0.43	No Data
2H	23.68	0.36	0.12
2N	33.02	0.48	No Data
2U	13.69	0.30	No Data
4A	12.12	0.46	No Data
4G	13.33	0.21	0.26
4N	15.42	0.40	0.09
9C	9.85	0.19	0.19
9G	6.11	0.11	0.22
9N	4.77	0.12	0.14
9Z	6.18	0.15	0.21
WEIGHTED AVG.	8.13 days	0.14 days	0.17 days

TABLE VI-11

rule, one can think of current policy as using a value of zero for X.

The stock list experiment was run for two commodities -- 1H, consumable ships' mechanical parts, managed by SPCC, and 2N, repairable ships' electronic components, managed by ESO. For each commodity a base case was run, assuming that the current stock list constituted 100 percent of the items that could be stocked. Other base case values are:

COG	SHORTAGE COST	STOCK-OUT RISK	
		Maximum	Minimum
1H	$ 25	.50	.01
2N	$ 10	.99	.01

Table VI-12 contains the results for the base case, three values of X other than zero and the effect of changing shortage cost or risk constraints. Clearly, as the value of X decreases, line items stocked, gross supply availability, and inventory increase; requisition response time diminishes. It is interesting to note that, as in the last case of 1H cog, a large (20 fold) increase in shortage cost has little effect on performance. This phenomenon, discussed more fully in connection with Experiment 8, results from the low ceiling (0.50) placed on risk of stock-out.

EFFECT OF CHANGES IN WHOLESALE STOCKING CRITERIA

CASE	STOCKED ITEMS	GROSS AVAILABILITY	AVERAGE ON HAND	RESPONSE TIME
		1H Cog		
Base Case	100 %	91.5 %	$120.5 M	9.67 da.
X = .02	32.6%	66.4 %	66.65M	12.04
X = .002	44 %	81.6 %	89.7 M	10.6
X = .00002	45 %	82.9 %	98.4 M	10.48
X = .00002 1/	45 %	83.3 %	99.5 M	10.44
		2N Cog		
Base Case	100 %	62.5 %	15.04M	34.04 da.
X = .002	16.2%	25 %	1.95M	56.40
X = .0002	35 %	52 %	10.8 M	40.45
X = .00002	36 %	54 %	11.55M	39.25
X = .00002 2/	36 %	62.1 %	15.20M	36.15

1/ High shortage cost ($500) used.
2/ Max risk is 0.50 vice 0.99.

TABLE VI-12

The data on 2N cog lead to several interesting conclusions. First, one can, by stocking a little more than 1/3 of the items presently carried and by changing no other policy variable, achieve a requisition response time only 5.2 days greater than that now enjoyed. Second, stock range and shortage cost are not the only determinants of performance. The last two cases for 1N cog vary only in that the ceiling on risk has been lowered from 0.99 to 0.50. The result is a significant increase in inventory and a significant improvement in performance by either of two measures. The final conclusion from Table VI-12 is that policies which lead to equal performance by one standard do not by another. The last case and base case for 2N yield almost identical gross supply availabilities and inventory values, yet the requisition response time under the current policy of broad stockage is significantly superior. This is due to the fact that in 2N cog a backordered requisition for a stocked item can be satisfied in 149 days, whereas spot procurement of a not-carried item requires 226 days.

The most severe reduction in stock range displayed in Table IV-12 should produce the following annual dollar savings:

	1H Cog	2N Cog
Item management savings	$ 1,118,000	$ 41,000
Inventory holding savings	7,270,000	1,767,000
Spot buy costs	- 1,783,000	- 3,600
Net Savings	$ 6,605,000	$1,804,000

Experiment 8 - This experiment investigates the effect on performance of two important policy variables used in wholesale inventory management -- the implied shortage cost and the constraints (floor and ceiling) on the risk of stock-out computed using a particular shortage cost. These variables, the prime determinants of safety stock and hence supply availability, are locally controlled variables in the Navy's Uniform Inventory Control Point ADP System. The only restriction placed on the ICPs is that the variables be set so as not to exceed funds allotted to the ICP.

Experiment 8 was conducted for four of the commodities in the S^4 study. The results for two cogs are shown in Table VI-13; results for the remaining two cogs are quite similar. For both commodities in Table VI-13 the minimum allowed risk is 1%. The base case represents the policies in effect at the time the experiment was run.

From the basic data in Table VI-13, many possible comparisons can be made; three will be discussed here.

(a) Reducing 1H investment from $120.5 million to $92.5 million

Increase in response time	1.63 da.
One-time investment saving	$28 million

EFFECT OF CHANGES IN SHORTAGE COST AND RISK CONSTRAINT AT ICP

CASE Short Cost	Max. Risk	GROSS AVAILABILITY	AVERAGE ON HAND	RESPONSE TIME
		1H COG		
$200	0.50	91.9%	$121.0M	9.66 days
25*	0.50	91.5	120.5	9.67
0.01	0.50	90.2	118.5	9.79
200	0.99	86.9	105.0	10.10
25	0.99	81.8	97.0	10.56
0.01	0.99	73.6	92.5	11.30
		4N COG		
500	0.50	86.3	54.2	8.23
500	0.99	83.4	40.8	8.49
150*	0.99	78.5	38.9	8.70
0.03	0.99	54.7	34.3	11.02

*Base (i.e., Current) Case

TABLE VI-13

Continuing saving in holding costs	$3.78 million/yr.
Increased spot buys, assuming proportional increase in spot buys as availability drops	35,164/yr.
Increased spot-buy cost	$1.28 million/yr.
Net savings	2.5 million/yr.

(b) Reducing 4N investment from $38.9 million to $34.3 million

Increase in response time	2.32 days
One-time investment saving	$4.6 million
Continuing savings in holding cost	$.62 million/yr.
Increased spot buys	1228/yr.
Increased spot buy costs	$.05 million/yr.
Net savings	$.57 million/yr.

(c) Increasing 4N investment from $38.9 million to $54.2 million

Decrease in response time	0.47 da.
One-time investment increase	$15.8 million
Continuing holding cost	$2.07 million/hr.
Decreased spot buys	403/yr.

Decreased spot buy cost	$.02 million/yr.
Net cost	$2.05 million/hr.

Looking at the figures in Table VI-13 more generally, it is possible to draw several conclusions. The most obvious is that the law of diminishing returns applies to Navy inventories. In 1H cog $4.5M would "buy" three-fourths of a days response time if response time were now 11.3 days. On the other hand, a third that mount ($1.5M) buys only 0.12 days response time when the average response time is 9.79 days. Hence at 11.3 days response time a dollar of inventory is twice as useful as it is at 9.8 days response time. The reduction in marginal utility of inventory is even more dramatic in the case of 4N material.

The second conclusion of the experiment is that the maximum risk constraint (especially when set at 0.50 so that, practically speaking, no item has a negative safety level) has a profound influence on inventory and performance. In the first 3 cases for 1H cog neither investment nor performance vary significantly, despite the fact that shortage cost varies by a factor of 20,000.

Third, equal policy settings do not produce equal performance in different inventories. Current management of 4N material leads to gross availability of 78%; roughly the same policies (shortage cost of $200 and maximum risk of .99) would lead to almost 87% gross availability in 1H cog.

Even more startling is the fact that this higher gross availability in 1H cog leads to a significantly longer mechanic's wait (1.4 days longer) than in 4N cog. This situation may be the result of heavier stockage (at unknown cost) of 4N material at lower echelons. Whatever the case, the final conclusion of the experiment is that gross availability at the wholesale echelon is not the sole determinant of the mechanic's delay time.

For 1H cognizance material, experiments 7 and 8 combined reveal the consequences of a wide variety of management strategies. These are plotted in Figure VI-4. Current performance lies near the lower end of the curve marked "MAX. RISK = 0.50". Given the present average inventory of 1H cog (about $120 million) there appears no reason to change management strategy. Increasing the maximum risk to 0.99 would probably achieve current results but would be psychologically less satisfying. On the other hand, as inventory levels diminish toward $110 million, a wider spread of risk becomes increasingly attractive. And, if authorized inventories should fall much below $100 million, the manager should seriously consider reducing the 1H stock list. Conversely, there is no incentive to reduce the stock list at the present time, especially if slow-moving items are being eliminated from shipboard inventories.

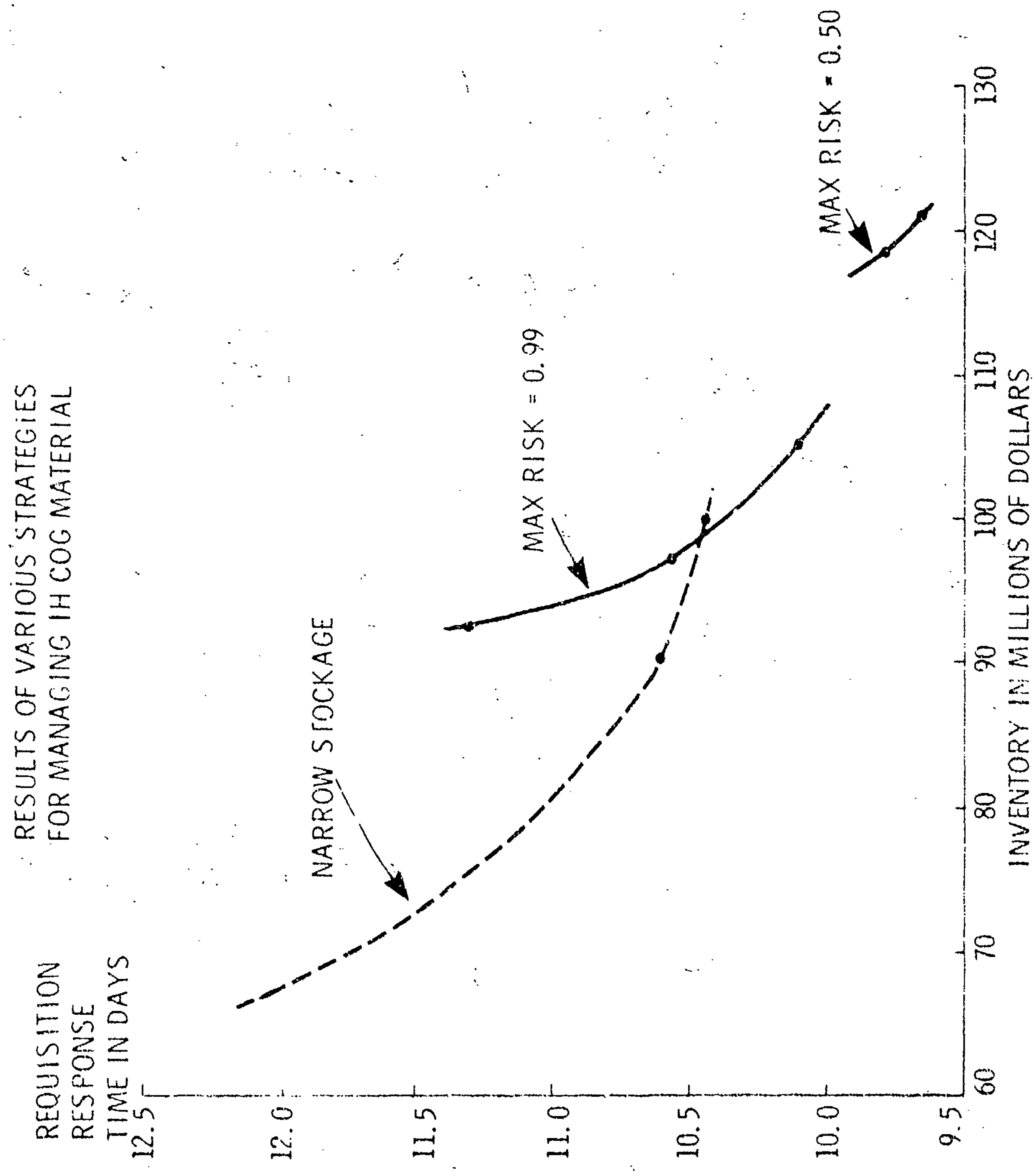

RESULTS OF VARIOUS STRATEGIES
FOR MANAGING IH COG MATERIAL
REQUISITION
RESPONSE
TIME IN DAYS
12.5
12.0
11.5
11.0
10.5
10.0
9.5
60
70
80
90
100
110
120
130
INVENTORY IN MILLIONS OF DOLLARS
NARROW STOCKAGE
MAX RISK = 0.99
MAX RISK = 0.50

FIGURE VI-4

Experiment 9 - Reduction in spot-buy and backorder times at the ICPs and DSCs is the subject of this experiment. Although the benefits of a one-day reduction in these two functions are slight, the throughput times are of such long duration that the benefits of multiple day reduction warrant investigation. A somewhat arbitrary goal of 100 days total throughput time was postulated for spot buys and backorders. The basis for selecting the goal was that, with two exceptions, throughput times in Navy cogs exceed this goal; incidentally, with two exceptions, DSA throughput times are less than 100 days.

The benefits to requisition response time of achieving the 100 day goal are displayed in Table VI-14. In some cases the potential benefits are quite impressive; in other cases they are negligible. It must be remembered that various organizations other than the ICP account for segments of backorder and spot-buy time. In back-ordering cog symbol 1A material, for example, 35 days are spent getting the requisition to the ICP (SPCC in this case), issuing it from the stock point, and delivering it to the Mediterranean. This currently leaves 143 days for all necessary actions at the ICP and manufacturing by the vendor. With a goal of 100 days, only 54 are available for ICP processing and manufacture. Thus the 100 day goal would in most cases be difficult to achieve, to say the least.

If an ICP's sole objective were to minimize requisition response time, then the ICP would backorder end-use requisitions only when the anticipated delivery date occurs before a spot-buy transaction could be completed. Further, one would expect that, if this objective were invariably sought, the average end-use backorder time would be one-half the spot buy time. It is clear from Table VI-14 that it is not. In fact, in only two cogs (4A and 1N) are the net times on spot buy at least twice as great as net times on backorder (exclusive of submission and delivery time.) Conversely, in three Navy cogs and all four DSA cogs, time on backorder exceeds time on spot buy. This suggests that ICPs are moving at least partially toward the objective of minimizing spot buy actions and of minimizing purchase of material in excess of established requisitioning objectives.

Experiment 10 - In this experiment, the inventories of six typical Sixth Fleet ships were reduced to 60 wartime days and 30 wartime days endurance in lieu of the 90 day level specified by OPNAVINST 4441.12 and now incorporated in both COSAL and SIM (Selective Item Management) computations. Preliminary results of the experiment are shown in Table VI-15. The reduction in gross supply availability is expressed in percentage points; thus a 3.2 point reduction might result from availability dropping from 60% to 56.8%.

The gross one-time saving in inventory for the entire Sixth Fleet amounts to $4.5 million and $12 million for the 60- and 30-day

EFFECTS OF REDUCING BACKORDER AND SPOT BUY TIMES TO 100 DAYS EACH

COG SYMBOL	CURRENT TIMES				RESPONSE TIME SAVING	
	Backorder	Spot-Buy	Submission and Delivery	Response	Backorder	Spot-Buy
1A	178 days	174 days	35 days	19.56 days	1.68 days	0.92 days
1H	154	163	41	10.33	0.52	0.52
1N	104	213	35	8.51	0.02	0.05
2A	132	205	31	19.31	1.60	1.16
2G	128	114	23	17.65	1.23	0.50
2H	147	211	33	23.68	3.16	3.24
2N	140	216	38	33.42	5.46	2.71
2U	132	98	35	13.69	0.87	-0.04
4A	93	170	35	12.12	-0.13	1.47
4G	147	181	34	13.33	1.53	0.61
4N	139	156	40	15.42	1.20	0.44

TABLE VI-14

EFFECT OF REDUCING ENDURANCE LEVELS OF SHIPS' STOCKS

SHIP	INVENTORY REDUCTION		SUPPLY AVAILABILITY REDUCTION	
	60-Day Endurance	30-Day Endurance	60-Day Endurance	30-Day Endurance
AOE-3	6.7%	15.5%	3.2 points	6.7 points
CG-10	7.6	21.9	1.7	5.8
DD-933	2.4	12.1	2.4	3.4
DDG-35	7.7	23.3	1.8	4.9
DLG-16	2.7	11.8	2.0	6.4
LPA-249	13.4	29.9	1.9	5.5
Average	7.4% or $75,000/ship	19.7% or $200,000/ship	2.1 points or 4%	5.6 points or 10.7%

TABLE VI-15

endurance cases, respectively. Using inventory holding costs in lieu of inventory value, the savings become $563 thousand and $1.5 million per year. From these gross savings must be subtracted the cost of increased DTO requisition preparation and receipt aboard ship, increased issues by the AFS (or NSC, Norfolk) and a proportional increase in CASREPT requisitions handled. The additional administrative expenses amount to $10,000 and $26,000 annually for the two cases under consideration.

Reducing endurance to 60 and 30 increases response time by 0.6 and 1.7 days respectively.

The Fleet Material Support Office is continuing work on this experiment both within the framework of S^4 and independently. Matters investigated will include assumptions about the form of demand distribution and rules for designating SIM items.

<u>Experiment 11</u> - Eliminate resupply function of AFS as well and end-use supply, but do not eliminate MATCONOFF screening function. Ships' stock replenishment will be accomplished by direct requisitioning on NSC Norfolk; transportation will be accomplished by MAC or APP and COD or remaining MLSF ships. End-use requirements (except high-priority ones satisfied through MATCONOFF) will also be filled by Norfolk. Compute reduction in shipboard availability, increase in response time, net workload increase at Norfolk, and FILL inventory value.

In running the experiment, it was assumed that (1) AFS availability would drop to zero, (2) screening availability would drop to 1/3 its present value, and (3) shipboard availability would

EFFECT OF ELIMINATING AFS

SUPPLY AND RESUPPLY FUNCTIONS

COG SYMBOL	REQUISITION RESPONSE TIME Current	Without AFS	Increase
1A	19.56 da.	21.66 da.	2.10 da.
1H	10.23	13.69	3.46
1N	8.51	13.03	4.52
2A	19.31	20.59	1.28
2G	17.65	17.65	0
2H	23.68	24.86	1.18
2N	33.02	33.35	0.33
2U	13.69	13.69	0
4A	12.12	12.14	0.02
4G	13.33	16.95	3.62
4N	15.43	16.19	0.76
9C	9.85	14.35	4.50
9G	6.11	11.55	5.44
9N	4.77	8.16	3.39
9Z	6.19	10.25	4.06
Average			3.80

TABLE VI-16

remain constant despite the loss of the AFS as a quick source of resupply. Given these assumptions, revised response times were computed and are displayed in Table VI-16. As one might expect, the increase in response time is severe (almost 47%) because the AFS satisfies approximately 20% of all demands arising aboard ship.

Offsetting this loss are cost reductions. An AFS costs $70.9 million to build and carries a $1.476 million load. These are one-time costs that could have been avoided if the AFS had not been built. On the theory, not necessarily correct, that three fleet issue ships are maintained in the Atlantic Fleet so that one may be deployed in the Sixth Fleet at all times, a total one-time cost of $213 million could have been avoided. Spread over the 20-year useful life of ship, this averages $10.7 million per year. Assuming that the cost of operating a ship each year is about 10% of its replacement cost, $21.3 million can be added to annual savings.

Against these savings are increased operating expenses in CONUS. An additional 26,600 issues must be made annually by Norfolk or some other supply activity at a cost of $31 thousand. Issued material must be delivered via MAC to Naples. Assuming 26 pounds per parcel and an additional 30,000 parcels per year, the extra transportation cost is $188 thousand.

Before removing an AFS from the Fleet, there are many factors to be considered, some of which are not related to peacetime requisition response time. One concerns the mode of delivery of resupply and end-use material. Fleet issue ships are specially constructed to facilitate transfer of stores at sea. In the absence of such a ship, combatants must return to a specified port monthly to resupply. This method of operation implies careful spotting of incoming stores at the proper Mediterranean port, detachment of the combatant from its task force for extended periods (or movement of the entire task force to the appropriate port), excessive steaming to the port containing the stores, and increased chance of sabotage because the ship's whereabouts for a large part of the month must be fixed in advance.

A useful convenience in peacetime because of its influence on response time, the AFS may be a _sine non qua_ of wartime operations, because it is one of the ships that permits a task force to "pick-up and go" in an emergency, moving quickly to another part of the world, standing hundreds of miles off-shore for months at a time, dispersed over many square miles of ocean to reduce the consequences of enemy attack. Certainly, estimate of the benefits of an AFS in this ultimate situation is beyond the scope of this study. However, if one can isolate the purely peacetime supply costs and benefits of an AFS, others can judge whether the wartime benefits are worth the remaining costs.

Experiment 13 - Assume that all material to correct a failure is ordered simultaneously and at the beginning of the maintenance action. Recompute mean supply response time and equipment operational availability.

This and the next four experiments were run on the Converter (a) to demonstrate the use of the device by itself, (b) to show how the Converter utilizes the output of the Synthesizer and (c) to motivate other researchers to investigate further those experiments that appear to produce the most beneficial results. Converter experiments are properly the last link in a chain of events something like this:

o Conceive of a change that would reduce throughput time or increase supply availability in some echelon.

o By means of the Inventory Simulators or Process Analyzers and external cost analyses, calculate the benefits of the improvement and the cost of making it.

o Feed performance results into the Synthesizer to arrive at a new distribution of requisition response times by cognizance symbol.

o Using the newly developed distribution, simulate 1000 repair actions in the Converter to estimate a new MSRT and other quantities of interest.

Unfortunately, scheduling of the study effort did not permit the orderly development of experimental results in this manner. Instead, the distributions of requisition response times collected during the convass of Sixth Fleet ships were used to arrive at base case values in the Converter. The requisition response time distributions were then modified in a manner believed to be consistent with the objective of the experiment and the Converter rerun.

For Experiment 13, modification was not necessary because the contemplated change occurs within the ship and specifically within the maintenance organization aboard ship. The base case results are displayed in Table VI-17, showing the mean, 90th percentile, and

BASE CASE RESULTS OF CONVERTER RUNS

EQUIPMENT	SUPPLY RESPONSE TIME Mean	90th Pctl.	99th Pctl.	SERIAL REPAIRS	OPERATIONAL AVAILABILITY
AN/SPS-10F	9.62 da.	28.5 da.	82.5 da.	129	.6406
AN/SPS-40	13.51	37.5	165	146	.3065
AN/SQS-23	6.83	21.5	67.5	75	.7522
AN/SRC-16	9.43	26.5	165.0	88	.4947
AN/UPX-1	6.47	23.5	57.5	123	.9065
AN/UPX-12	6.40	22.5	82.5	92	.9471

TABLE VI-17

99th percentile supply response time resulting from simulating 1000 repairs. The number of repairs involving serial requisitioning and the equipments' operational availability are also displayed.

Table VI-18 indicates the benefits to be received from eliminating serial requisitioning. The percent of serial repairs ranges from 7.5 to 14.6 percent of all repairs, depending on equipment, yet MSRT is reduced between 1.5 and 4.8 percent by eliminating serial requisitioning, while the improvement in A_o ranges from 0.2 to 2.5 percent. Nor are the absolute or percentage improvements in one measure closely ranked with those in either of the other measures. All this simply implies that there are many factors influencing both MSRT and A_o.

BENEFITS OF ELIMINATING SERIAL REQUISITIONING

EQUIPMENT	MEAN SUPPLY RESPONSE TIME		OPERATIONAL AVAILABILITY	
	New	Reduction	New	Increase
AN/SPS-10F	9.23 da.	0.39 da.	.6501	.0096
AN/SPS-40	13.01	0.50	.3143	.0078
AN/SQS-23	6.73	0.10	.7547	.0025
AN/SRC-16	9.09	0.34	.5038	.0091
AN/UPX-1	6.24	0.23	.9094	.0029
AN/UPX-12	6.11	0.29	.9493	.0021

TABLE VI-18

Reduction or elimination of serial requisitioning involves additional training of maintenance personnel, improved diagnostic manuals, or additional automatic test equipment. Estimation of the costs or payoffs of such changes lies outside the competence of the study group. However, it is clear that if the cost of eliminating serial requisitioning were the same per unit installed for all six equipments, one would want to concentrate effort and money first on the AN/SPS-10F, since investment in this equipment promises the greatest benefits in increased operational availability.

Experiment 14 - Assume that the AFS replenishes each ship twice monthly. Estimate a revised requisition response time distribution for each commodity and recompute mean supply response time and operational availability. This experiment was simulated by cutting in half 50 percent of the shipboard - observed response times that lay in the range from [illegible] to 31 days, on the theory that half the material satisfied in this time span originates on the AFS. The benefits in terms of MSRT, displayed in Table VI-19, seem to be nearly independent of equipment, while the increase in A_o for the last two equipments is relatively small because the A_o is very high under normal conditions.

The cost of more frequent AFS resupply will depend on how the increase is effect. The most obvious way is to station two AFSs in the Mediterranean. If the current deployment rate (33%) is to remain in force, then two additional AFSs will be required in CONUS. This solution incurs one time costs of 3 X $70.[illegible] million, or $213 million, for new ships and between $1.5 and 3.0 million for additional FILL material plus $21.3 million in extra operating expenses, on the assumption that annual operating costs amount to about 10 percent of the cost of the ship.

The costs just given are maximum values. For example, simply by increasing the deployment rate from 33% to 40%, costs could be

EFFECTS OF MORE FREQUENT AFS RESUPPLY

EQUIPMENT	MEAN SUPPLY RESPONSE TIME		OPERATIONAL AVAILABILITY	
	New	Reduction	New	Increase
AN/SPS-10F	8.70 da.	0.92 da.	.6631	.0225
AN/SPS-40	12.55	0.96	.3218	.0153
AN/SPS-23	5.92	0.91	.7771	.0249
AN/SRC-16	8.49	0.94	.5206	.0259
AN/UPX-1	5.69	0.78	.9164	.0099
AN/UPX-12	5.59	0.81	.9533	.0062

TABLE VI-19

reduced one-third. On the other hand there may be hidden expenses involved in more frequent resupply, such as the need for the combatant to spend more time alongside the AFS, ..ence less time with its task force.

EFFECTS OF FASTER DELIVERY FROM CONUS

EQUIPMENT	MEAN SUPPLY RESPONSE TIME		OPERATIONAL AVAILABILITY	
	New	Reduction	New	Increase
AN/SPS-10F	9.00 da.	0.62 da.	.6558	.0152
AN/SPS-40	12.72	0.79	.3191	.0126
AN/SQS-23	6.40	0.43	.7637	.0115
AN/SRC-16	8.83	0.60	.5109	.0162
AN/UPX-1	5.92	0.55	.9135	.0070
AN/UPX-12	5.92	0.48	.9508	.0037

TABLE VI-20

Experiment 15 - Assume that material can be delivered five days faster from CONUS by subtracting five days from every elapsed time greater than 21 days. This can be thought of as a continuation of Experiment 6, in which the influence of a one day reduction in delivery (or communication) time on MRRT was investigated. A 5-day reduction in CONUS delivery time would, on the average, reduce MRRT by 0.70 days (See Table VI-11) and would reduce MSRT between 0.43 and 0.79 days. (See Table VI-20). The effect on operational availability varies widely, depending on the previous values of MSRT, MTTR, and MTBF.

No estimate has been developed of the cost of reducing CONUS response time. One method is to get requisitions to CONUS faster. As will be explained in Chapter VII, use of message in lieu of mail on all requisitions to CONUS should reduce overall CONUS throughput time by 2½ days. Better scheduling of IPG II requisitions through NSC, Norfolk should shave another 0.15 days off CONUS response time.

Experiment 16 - Assume that expedited action is taken on all spot-buys and backorders of end-use requisitions. This can be done by cutting in half all elapsed times exceeding 90 days and recomputing MSRT. This experiment yields the most dramatic reduction in MSRT, just as Experiment 9, similar in objective if not in detail, produced the largest reduction in MRRT of all the experiments aimed at improving requisition response time. For two equipments listed in Table VI-21 the improvement in A_o approximates 5 percentage points.

EFFECTS OF EXPEDITING BACKORDERS AND SPOT BUYS

EQUIPMENT	MEAN SUPPLY RESPONSE TIME		OPERATIONAL AVAILABILITY	
	New	Reduction	New	Increase
AN/SPS-10F	8.35 da.	1.27 da.	.6722	.0316
AN/SPS-40	10.56	2.95	.3591	.0526
AN/SQS-23	5.90	0.93	.7777	.0255
AN/SRC-16	7.79	1.64	.5418	.0471
AN/UPX-1	6.03	0.44	.9120	.0055
AN/UPX-12	5.80	0.60	.9517	.0046

TABLE VI-21

Because the study team has thought of no way in which backordering or spot buying could be expedited to the extent suggested in either Experiment 9 or 16, there is no estimate of the cost. It should be observed, however, that the improvements proposed in each experiment are quite ambitious.

Experiment 17 - Assume that shipboard gross availability is reduced five percentage points for each commodity. Recompute mean supply response time and operational availability. The only experiment in this group of five that entertains the possibility of degrading operational availability, it is closely related to Experiment 10, which assesses reduction of COSAL endurance levels to 60 and 30 wartime days. In fact, the result of reducing the prescribed endurance of the COSAL to 30 days is a 5.6 percentage point reduction in COSAL effectiveness. Therefore, allowing for the imprecise way in which Experiment 17 had to be conducted, one can estimte, from the figures in the last column of Table VI-22 what the ultimate consequences would be of reducing COSAL stocks about $200,000 per ship.

CONSEQUENCES OF REDUCED COSAL EFFECTIVENESS

EQUIPMENT	MEAN SUPPLY RESPONSE TIME		OPERATIONAL AVAILABILITY	
	New	Increase	New	Reduction
AN/SPS-10F	10.49 da.	0.87 da.	.6208	.0198
AN/SPS-40	14.41	0.90	.2933	.0132
AN/SQS-23	7.53	0.70	.7340	.0182
AN/SRC-16	10.33	0.90	.4722	.0225
AN/UPX-1	7.12	0.65	.8984	.0081
AN/UPX-12	6.94	0.54	.9431	.0040

TABLE VI-22

Experiment 18 - For those legs subject to modelling by the Process Analyzer, assume that workload is decreased by 20 percent and then increased either by 20 percent or to the maximum capacity of the organization. Recompute the mean and distribution of throughput time for the leg.

Experiment 19 - Estimate the effect on througnput time of changing processing resources in each leg approximately 10 percent above and below current values.

These two experiments were run jointly for requisitions processed from receipt to the point of shipment from NSC Norfolk. Table VI-23 shows the probability that an IPG I or II requisition will clear Norfolk in a specified number of hours under the following circumstances:

- current workload and workforce (headed "BASE ARR", for basic arrival rate, and "BASE CAP" for basic capacity)

- current workforce but a 20 percent increase in workload, or arrival rate (headed + 20% ARR)

- current workload but a 10 percent increase in capacity (+10% CAP)

- current workload but a 20 percent reduction in workforce and hence capacity (-20% CAP)

- current workload but a 40 percent decrease in capacity (-40% CAP).

It is clear from Table VI-23 that, short of a major increase in workload or a sizeable reduction in the workforce, both IPG I and II requisitions should continue to be processed at their current rate, given that the estimates of capacity and workload are reasonably

DISTRIBUTION OF REQUISITION THROUGHPUT TIME

AT NSC, NORFOLK

HOUR TO COMPLETE	BASE CAP BASE ARR	BASE CAP +20% ARR	+10% CAP BASE ARR	-20% CAP BASE ARR	-40% CAP BASE ARR
		Priority Group I Requisitions			
1-2	0	0	0	0	
3	.059	.059	.059	.059	.059
4	.081	.081	.081	.081	.081
5	.191	.190	.193	.189	.163
6	.176	.176	.176	.177	.170
7	.103	.103	.102	.108	.114
8	.062	.062	.061	.060	.073
9	.045	.045	.045	.047	.047
10	.042	.042	.042	.041	.043
11	.042	.042	.042	.041	.042
12	.042	.042	.042	.041	.042
13	.042	.042	.042	.041	.042
14	.042	.042	.042	.041	.042
15	.034	.034	.034	.033	.034
16	.028	.028	.028	.027	.028
17	.009	.010	.009	.013	.015
AVG HRS	7.765	7.777	7.760	7.798	7.934
		Priority Group II Requisitions			
1-17	0	0	0	0	0
18	.023	.023	.023	.023	.023
19	.041	.041	.041	.041	.041
20	.091	.081	.094	.067	.051
21	.121	.114	.122	.04	.058
22	.124	.124	.124	.121	.070
23	.124	.125	.124	.123	.077
24	.124	.125	.124	.124	.083
25-40	0	0	0	0	0
41	.125	.125	.125	.124	.083
42	.102	.103	.102	.101	.067
43	.083	.084	.083	.083	.048
44	.034	.046	.031	.057	.051
45	.004	.011	.002	.022	.051
46	.001	.001	.001	.001	.045
47-90	----	.001	----	.001	.262
AVG HRS	28.810	29.485	28.669	29.670	40.024

TABLE VI-23

accurate.* However, capacity reductions, if carried too far, will result in serious degradation of service, as the last column in Table VI-23 suggests. At 40 percent capacity reduction, IPG I requisitions still move through the system rapidly because they are given first priority. IPG II requisitions, on the other hand, show a serious increase in average throughput time; IPG III data, if displayed, would show an even greater slowdown. Furthermore, a relatively small further decrease in capacity would cause requisition processing at Norfolk to "blow up", at least for IPG III requisitions. Under these conditions the backlog of Group III requisitions would grow without bound, resupply of the AFS (and hence resupply of combatant ships) would be impossible, and an intolerable burden would be placed on the remaining IPG I and II processing resources.

The reason for the very consistent throughput times despite minor variations in capacity and workload is that Norfolk's requisition processing workforce was operating considerably below capacity at the time of the study. Thus situation is by no means undesirable. In any service organization, and particularly one serving a military activity, it is necessary to have sufficient capacity to take care of surges in demand. Because of the nature of international situations and the operations of Navy ships Norfolk's surge peak is likely to be much higher than that of a similar commercial organization. Further, if a private company is unable to cope with the surge, it loses sales and profits. If Norfolk cannot handle the demand, the Sixth Fleet may lose an engagement. Indeed, management at NSC, Norfolk, may have deliberately overstaffed requisition processing at the expense of other functions on the theory that timely requisition processing ought to be and is NAVSUP's prime objective.

Under the best of conditions, theoretical capacity cannot be achieved. For one thing, the physical plant may be such that people must be frequently moved from one location to another at loss of considerable time. Then, either because of plant layout or specialization, each of several work stations must be manned regardless of the amount of work flowing through the station. Finally no group can operate at maximum capacity for long periods of time.

To a large extent what determines the throughput time at Norfolk are "institutional delays", those deliberate or evolved rules about batching and scheduling the flow of work through the organization. In fact, a requisition spends most of its time waiting to be moved by a messenger, waiting to be introduced into a computer, or waiting for the workforce to come to work. Only during a small fraction of

*The utilization and throughput estimates given here are not inconsistent with those in Requisition Throughput Time Simulation for NSC San Diego; M. G. Lynch and C. H. Ulrich; U. S. Naval Postgraduate School; Monterey, California; March 1973 its time at Norfolk does a requisition wait for service from an employee who is on duty; an even smaller fraction is spent being actively processed by the employee.

Experiment 20 - Related to Experiment 12, this experiment looks analytically at the consequences of reducing resupply, not end-use, response time. It is assumed that resupply time for those items ships requisition from CONUS is reduced by having the material air shipped (via MAC or APP) and that resupply time for the AFS is shortened by insuring that NSC Norfolk is able to resupply 100 percent of the AFS demands. Although the simulative approach would be more accurate, parametric analysis has been used in this experiment to increase speed and decrease cost of analysis and to demonstrate the use of the analytic approach.

The lead time experienced in resupplying a combatant ship's storeroom can be expressed as:

$$L_1 = a'_2 P_2 \bar{t}_2 + (1 - a'_2) P_2 (\bar{t}_2 + 30) + (1 - P_2) a_4 \bar{t}_{4,i} + (1 - P_2) a_5 \bar{t}_{5,i} + (1 - P_2)(1 - a_4 - a_5) \bar{t}_7$$

The lead time experienced by the AFS is:

$$L_2 = a'_4 t'_4 + a'_5 \bar{t}_{5,2} + (1 - a'_4 - a'_5) \bar{t}_7$$

where symbols have the following meanings and are assigned the indicated minimum, maximum, and most likely values:

a'_2 = MLSF net supply availability (90, 96, 98%)

P_2 = Pr (ships' requisition is for FILL item) (60, 80, 85%)

$\bar{t}_2$ = time to resupply routinely by LOGREP (45, 45, 45 da.)

$\bar{t}_{4,1}$ = IPG III resupply time from Norfolk, given air transportation to the Med. (14, 23, 32 da.)

$\bar{t}_{4,1}$ = IPG III resupply time from Norfolk, given surface transportation to the Med. (48, 48, 60 da.)

$\bar{t}_{5,1}$ = IPG III resupply time by referral, given air transportation to the Med. (23, 35, 47 da.)

$\bar{t}_{5,2}$ = IPG III resupply time by referral, given surface transportation to the Med. (51, 51, 65 da.)

$\bar{t}_7$ = IPG III backorder time. (110, 130, 150 da.)

a_4 = Fraction of Sixth Fleet requisitions coming to CONUS and satisfied by Norfolk. (40, 58, 75%)

a_5 = Fraction of Sixth Fleet requisitions coming to CONUS and satisfied by referral. (24, 33, 57%)

a'_4 = Norfolk's net effectiveness in resupplying FILL requisitions. (50, 60, 70%)

a'_5 = System's effectiveness on FILL requisitions after Norfolk supplies all possible material. (10, 14, 20%)

t'_4 = Routine resupply time via pipeline ship. (30, 45, 45 da.)

These values were used to arrive at 3 estimates of resupply time under current conditions:

	Via Surface from CONUS
Shortest reasonable time	46.2 days
Most likely time	48.3
Longest reasonable time	55.0

The spread between the three figures is slight because most resupply material is provided by the AFS and because its availability is always high.

The use of air vice surface delivery of those items that must be resupplied from CONUS would change the total leadtime (including those items supplied by the AFS) as follows:

	Via Air from CONUS
Shortest reasonable time	41.3 days
Most likely time	45.1
Longest reasonable time	46.8

Thus, air delivery has at best a 9 day influence on overall resupply time; the actual improvement is probably less than 5 days.

The cost of air delivery is $0.239 per pound from Norfolk to Naples. The cost of delivery by MSC (exclusive of packing) is approximately $0.065 per pound. The average price per pound via QUICKTRANS is $0.285; fifty-five percent of the parcels must move over QUICKTRANS as well as MAC. A reasonably high estimate of the number of parcels to be shipped is 28,000, the total number of mechanics' requests ultimately filled by CONUS. Assuming that the average parcel weighs 26 pounds, the figure usually quoted by Norfolk for parcel post the total annual cost of airlifting IPG III material to combatants in the Sixth Fleet should not exceed $243,000.

NSC Norfolk is now able to supply from stock about 60% of the resupply requisitions submitted monthly by the AFS. If this figure could be raised to 100%, many administrative costs aboard the AFS, at Norfolk, and elsewhere in the system could be avoided or reduced. Given the current levels for DSA type material at Norfolk, this improvement could be made by investing about $1.24 million in stock. Further, resupply time to the AFS would be reduced 10 to 40 days; this, in turn, might reduce resupply time to customer ships. In fact, because the AFS now performs so well, the reduction would be slight:

	100% AFS Resupply by Norfolk
Shortest reasonable time	44.0 days
Most likely time	46.0
Longest reasonable time	53.5

If both of the proposals investigated here were adopted, combatant ship resupply time would probably assume these values:

	100% AFS Resupply by Norfolk Air Resupply of Combatants
Shortest reasonable time	41.2 days
Most likely time	43.4
Maximum reasonable time	44.9

or about 5 days less than present resupply times.

It should be noted that delivery of direct-turnover (DTO) material by air is assumed in the S^4 study and used in practice, at least to the extent that organic aircraft and ships' operations permit. It should also be noted that air resupply may be quite profitable for the heavy personnel concentrations now near Rota, Spain, and developing in Athens, Greece. With respect to AFS resupply, high effectiveness at Norfolk would, of course, be more critical if AFS stock levels were reduced significantly.

It is not possible to compute at this time the benefits in terms of MRRT of the two proposals investigated in this experiment, inasmuch as Experiment 12 and a counterpart experiment for the AFS have not yet been run.

C. Experiments Not Completed

The experiments listed below had not been completed at the time of writing the Final Report. If they are subsequently completed, they will be the subject of an addendum or of separate Technical Memoranda.

Experiment 2 - Mathematically similar to Experiment 7, this experiment seeks to eliminate from the COSAL all items whose probability of any demand during a year per dollar invested in the item does not exceed some arbitrary value. As this arbitrary threshold is changed the range, dollar value and effectiveness of the COSAL change.

Experiment 3 - An extension of Experiment 2, this experiment proposes the application of economic order quantities and variable safety levels to the items remaining on the COSAL after the second experiment is completed. The order quantity is the standard Wilson EOQ; the reorder levels are designed (a) to give a constant probability of stock-out for all items or (b) to minimize units short.

Experiment 12 - Estimate the gross effectiveness of the COSALS of selected ships in the S^4 sample if the routine resupply time is reduced from that assumed in initial runs to (a) routine resupply times characteristic of the Sixth Fleet and (b) response times characteristic of IPG I and II requisitions in the Sixth Fleet.

VII. DISCUSSION AND CONCLUSIONS

A. Additional Modelling

The entire cost of the 2-year Ships Supply Support Study was $467,000, including salaries (with fringe benefits but not overhead), contract services, computer rental, travel, and printing. The source and use of funds is displayed in Table VII-1. The costs cited include research on design of realistic queuing models,

SOURCE AND USE OF FUNDS - S^4 STUDY

SOURCE		APPROPRIATION	
	RDT&EN	MPN	O&MN
OPNAV	104,500	3,400	0
NAVSUP	140,300	3,900	46,800
FMSO		3,900	119,700
MSO		0	39,300
MISC.	2,500	2,600	0
Total	247,300	13,800	205,800
USE			
Salaries	52,800	13,800	205,800
Computer	37,500		
Travel	4,200		
Contractor	152,800		
Total	247,300	13,800	205,800

TABLE VII-1

location of data sources as well as data collection, and construction of computer models of several organizations common to more than one support system.

Extension of the models to other Fleets and, of course, maintenance of the models would be far less expensive than the original design. Table VII-2 contains estimates of the cost of designing and maintaining additional models. Maintenance involves the collection of performance and cost data annually to maintain the currency of the models. Maintenance costs (both personnel and computer) may vary widely depending on how many models require maintenance and how many experiments or analyses are to be run annually. Support of all the operating forces and major industrial installations could be modelled at a one-time total cost of $145,000;

MODELLING AND MAINTENANCE COSTS

FLEET MODELLED	MODEL TO BE DESIGNED	MAN YEARS	COMPUTER RENTAL
Seventh Surface	Flow and Inventory in WESPAC Depot	1/2	$ 2,000
	AFS and Screening Inventory	1/3	2,000
	NSC Oakland Flow	1/6	500
	Pacific Synthesizer	1/6	500
	Total	1-1/6	$ 5,000
Overseas Aviation	AVCAL Inventory	3/4	$ 4,000
	ASO Inventory and Flow	1-1/2	5,000
	Aviation Synthesizer	1/6	500
	Aviation Converter	1	8,000
	Total	3-5/12	$ 17,500
CONUS	Multi Warehouse Simulator	1	$ 6,000
	CONUS Synthesizer	1/6	500
	Total	1-1/6	$ 6,500
Annual Maintenance		1/2 to 2	$ 5,000 - $20,000

TABLE VII-2

maintenance and exercising of the models could be done for less than $60,000 annually.

B. Use of Models in Budget Process

Because the S^4 computer programs are able to link resource usage to performance, measured in several ways, the programs can be used to shed light on budget issues. In order to accomplish this, it would be necessary (1) to anticipate possible budget issues (such as elimination of TOR items or reduction of endurance period for COSAL items), (2) to gather whatever special data are needed for analysis and the most current data for the standard S^4 runs, (3) to run appropriate experiments or analyses to test hypotheses implicit in the budget issues, and (4) to present results of analyses to budget preparation and review officials.

C. Use of Models in Equipment Analysis

The experiments in Chapter V demonstrate that the S^4 computer programs, including the Converter, are capable of estimating both requisition response time and supply response time and of projecting the effect of changes in the support system. Such changes may not be obvious by inspection nor are alternative changes always of equal cost. The S^4 programs constitute a device for assessing the cost and benefits of alternative equipment support methods, for comparing the cost of improved operational availability by means of improved reliability and maintainability as well as increased supply support, and for isolating those quipments for which enhanced supply support cannot materially improve equipment availability. The programs can be used to evaluate support of equipments in being and those for which development is sufficiently advanced to permit estimate of failure rates and repair times.

D. Requisition Submission and Processing Time

The description of requisition flow in Chapter III and Table VII-3 indicates (1) that almost half the IPG II requisitions sent from the Sixth Fleet to NSC, Norfolk go via mail, (2) that 50 percent of the messages require more than 1 day to leave the ship, (3) that 14 percent of the messages are in the communication system more than 12 hours, (4) that about 12 percent require more than 48 hours after arriving at Norfolk to enter its computer, (5) that IPG II and III requisitions are processed only once daily on the computer, (6) that IPG III requisitions are delayed 22 hours before entering the AUTODIN system and (7) that IPGs II and III are delayed between 4 1/2 and 7 days if missing a stock number. The submission and transmission time are clearly in excess of UMMIPS standards.

Several of these undesirable situations could be avoided or at least mitigated by providing computer-equipped ships with AUTODIN terminals, as proposed in CNM letter of 17 January 1973 and endorsed by CNO letter, serial 0941C/2564 of 30 May 1973. AUTODIN would relieve the operational communication system of the burden of logistics traffic. It would not create additional workload aboard the ship as a whole and would avoid the special clearances sometimes required of message traffic. It would avoid the conversion of messages to MILSTRIP requisition format at Norfolk, thus eliminating handling by the message center, customer service, and key punch room. Linking AUTODIN transmission with the DAAS (Defense Automatic Address System) would permit automatic search for a stock number. Admittedly, AUTODIN requisitioning would neither force frequent input to the computer nor avoid the 22 hour delay in transmission from Norfolk via AUTODIN. However, it would eliminate some impediments to rapid processing which now exist.

An AUTODIN terminal and satellite system such as that envisioned in the CNM letter of 17 January 1973 might reduce communication time between Sixth Fleet ships and NSC, Norfolk as follows:

REQUISITION SUBMISSION AND PROCESSING TIMES

(IPG I and II Requisitions)

DAYS TO COMPLETE	MESSAGES Mechanic To Communicator	MESSAGES Ship to NAV-COMSTA, NFK	MESSAGES NAVCOMSTA To NSC Computer	MAIL Mechanic To NSC Computer
0 - ½		305	96	
½ - 1	182	35	129	
1 - 1½		14*	38	
1½ - 2	115		26	
2 - 2½			41*	
2½ - 3	41			
3 - 4	6			1
4 - 5	5			35
5 - 6	4			52
6 - 7	0			23
7 - 8	1			8
8 - 9	3			9
9 -10	1			28
10 -11	0			19
11 -12	0			24
12 -13	0			5
13 -14	1*			10*
MEAN	31 Hours	13.1 Hours	22.2 Hours	201 Hours
OBSERVATIONS	359	354	330	214

*Frequency for this and all higher values

TABLE VII-3

Communication Leg	Present Method Message	Present Method Mail	Proposed Method AUTODIN
Mechanic to Communicator	31 hrs.		24 hrs.
Ship to COMSTA, NFK	13		6
COMSTA to NSC	22		16
Total	66 hrs.	201 hrs.	46 hrs.
FSN Search at DLSC	108 hrs.	108	48 hrs.

If half the IPG I and II requisitions were sent from mechanized ships, the overall reduction in requisition response time for the Sixth Fleet would be 0.38 days.

An AUTODIN satellite communication system has many other obvious advantages, including (1) the ability to communicate between ships in the Sixth Fleet, (2) the elimination of message processing aboard ship and at COMSTA, Norfolk, (3) reduction of requisition processing effort at NSC, Norfolk, (4) reduced traffic and hence increased speed through existing message system and (5) use of AUTODIN system for other logistics and administrative traffic, including IPG III requisition transmission, status reporting, personnel strength accounting, etc. If, for whatever reasons, AUTODIN cannot be installed aboard ship or until installation is completed, other actions can and should be taken to reduce requisition submission and processing times. These include transmission of all IPG I and II requisitions by message, expedited message handling aboard ship and expedited processing at NSC, Norfolk.

Some of these can be accomplished at little cost; others will undoubtedly require revision of procedures, possibly new computer programs, and a period of experimentation.

E. Scheduling Requisition Input at NSC, Norfolk

As Table III-1 indicates, NSC Norfolk enters IPG II requisitions into the computer at 0500 daily to determine status and either to prepare picking tickets or to refer to the proper ICP/DSC. Both ESO and SPCC computers are in operation at least 3/4 of the day and could easily refer requisitions at once to a stocking NSC or shipyard.

Because Sixth Fleet messages arrive amost uniformly throughout the day, it should be possible to reduce requisition response time by 0.02 days simply by introducing IPG II requisitions into the computer on the same schedule observed for IPG I requisitions. Picking tickets would continue to be prepared on the current schedule. No computer programs need to be changed to accommodate the revised input schedule. In theory, no additional personnel need be hired because the total workload would remain constant. However, for purposes of discussion assume that two additional personnel must be hired to process IPG II requisitions from the Sixth Fleet during the second shift. This would cost $19,000 per annum.

F. Reduction of Technical Override (TOR) Items

The experiment in Chapter VI clearly indicates that while TOR items do contribute slightly to shipboard availability, the contribution is not commensurate with the funds invested in inventory. It is, therefore, concluded that OPNAV should continue its recently established policy of non-replenishment of TOR items and exclusion of new-equipment TORs from the COSAL and should, through the medium of the S^4 program, periodically reassess the effect of excluding TOR items.

G. Fleet Screening Operation

The experiment in Chapter VI suggests that the fleet screening operation conducted by the MATCONOFF, Sixth Fleet avoids approximately 100,000 requisition days of shortage per annum of material critically needed to correct casualties. In view of the modest resources in the operation ($50,000 per annum), it is concluded that it is alleviating high-risk shortages at low cost.

H. Long Term Demand Base for AFS

In comparing simulated supply availability for the AFS echelon with that observed during on 18 month period, it was noted that the simulated availability was equal to or less than the observed value in 2 cogs, but greater in 10 cogs. This is probably due to the fact that the simulation allowed demand to build up during the entire 18 month simulated period but that, during the period of observation, the deployed AFS would start collecting demand anew every 6 months. Since the period of observation, it has become the policy of the out-chopping AFS to transfer its demand histories to the AFS entering the Sixth Fleet. It is concluded that this policy should be continued.

I. Serial Requisitioning

Analysis of CASREPT and 3-M maintenance action data reveals that in 24 percent of the CASREPTS and 16 percent of all maintenance actions, 2 or more repair parts were needed. In these cases requisitioning was done serially 43 percent of the time. In other words, some items were requisitioned, received, and installed, after which additional parts were ordered in one or more batches. Serial requisitioning may be caused by several things, including:

(1) Incorrect or incomplete initial diagnosis of failure.
(2) Ordering incorrect part.
(3) Use of serial replacement as a means of fault isolation.
(4) Receipt of incorrect part even when correct part was ordered.
(5) Receipt of material in not-ready-for issue condition
(6) Loss or cancellation of requisition.

Whatever the cause, serial requisitioning has an adverse effect on supply response time and, hence, on operational availability.

J. Use of Military in Lieu of Postal Transportation

Recent changes in postal rates have placed mail service in a very poor position economically with respect to military airlift, as the tariff information in Chapter III indicates. This is true despite the fact that using MAC involves documentation and clearance costs. (Such costs could be reduced somewhat by sending consolidated shipment to Naval activities on the Mediterranean coast, who would then break the shipments into individual parcels for delivery to final destination.) Furthermore, from Norfolk, military transportation to the Mediterranean is faster than Military Ordinary Mail and, with the recent improvement in MAC performance cited in Chapter III, at least as fast as Air Parcel Post. Therefore, the use of MAC on all IPG I and II parcels destined for the Sixth Fleet would save at least $84,000 annually on technical parts alone without degrading service in any way.

The situation on shipments from NSC Oakland is different. Mailing to the Mediterranean via air parcel post, as is Oakland's current policy, is probably faster and certainly more expensive than shipping via QUICKTRANS and MAC. On the other hand, MOM at present seems to give about the same service as military air and is clearly cheaper. Savings from use of MOM in lieu of APP would amount to about $46,000 annually. However, the current fast MOM service would degrade considerably if the U. S. Postal Service discontinued its apparent practice of shipping MOM via air on a space-available basis. In this event, NSC Oakland might wish to consider military air transportation as the best combination of speed and cost.

It should be remarked that some steps have already been taken to substitute military transport for mail within CONUS. For example, NSCs Oakland and Norfolk have instituted an arrangement whereby material destined for customers within Norfolk's local delivery area is shipped from Oakland to NSC Norfolk via QUICKTRANS, there to be sorted and delivered by supply center trucks. This method should reduce transportation costs somewhat, especially on the shorter hauls, if the material never enters the U. S. Postal Service. As soon as it does, the Postal Service charges a fixed CONUS transportation rate based on service and weight but not on distance.

At this writing it appears that Navy shippers may be unfamiliar with recent changes in postal rates which both increase costs and make shipment within CONUS insensitive to distance shipped.

K. Improved MAC Service to Sixth Fleet

The data in Chapter III indicate that QUICKTRANS can move material from NAS Alameda to NAS Norfolk in about 50 hours while MAC covers the trip from NAS Norfolk to Naples, roughly the same distance, in slightly over 5 days. Furthermore, the two systems maintain about the same flight frequency over the legs in question. Unless there is a great disparity in load factors, MAC should apparently be able to cut its elapsed time in half.

L. Use of Air Transport to Resupply AFS

In the past NSC Norfolk has, on the specific advice of the deployed AFS, air shipped (via MAC or MOM) resupply material not-in-stock or not-carried at Norfolk instead of shipping it on the next departing pipeline ship. Norfolk has recently discontinued this practice. In view of the cost of air shipment and the slight improvement in combatant ship support resulting from air resupply (see Experiment 20, Chapter VI), it is concluded that resupply material should continue to be shipped by pipeline ship.

M. Revision to 3-M Data Collection System

It was noted in Section VI. A. that there is now no reliable source of information on delay of corrective maintenance action due to ships' operations and outside assistance. These two delays may well be significant in relation to active repair time and delays due to lack of parts.

N. Standard for Measuring Elapsed Time

In S^4, mean requisition and supply response times have been measured in clock hours and calendar days because (1) some supply response processes operate around the clock and (2) the mechanic must wait around the clock for replacement parts. Some of the analyses of raw 3-M data, however, are based on the number of operating hours between failures. Mixing time in operating and clock hours causes understatement of operational availability. It would appear to be a simple matter to express MTBF in clock hours. In any event, times must be expressed in a consistent fashion.

O. Response Time Measurement

At the inception of S^4 and even at this writing, there is no routine method of measuring shipboard requisition response time, except for requisitions associated with CASREPTs. Recently, NAVSUP has undertaken the reporting of response time by mechanized ships -- aircraft carriers, assault helicopter carriers, tenders, and supply ships. Although this reporting does not cover the entire fleet, it covers numerically about one half of fleet requisitions and can by extrapolation be used to estimate response time for other ships. It is concluded that NAVSUP should pursue this vital effort to completion.

P. Use of Queuing Models

Standard queuing models are generally not useful in estimating throughput time within a single Navy supply organization because throughput time is insensitive to all but major (i.e., 40 percent or greater) changes in workload or workforce. This results from the fact that at the activities studied capacity significantly exceeds actual average workload. At NSC, Norfolk, where workload ranged between 25 and 56 percent of capacity, certainly an important reason for the apparent underutilization is the need for a fairly high surge capacity to handle the crises characteristic of the operation and support of Naval forces.

An additional factor, undoubtedly present at Norfolk but immediately obvious in the analysis of ICP utilization rates, is that many employees have multiple functions, only one of which is requisition processing. Several work stations involved in requisition processing at the Ships Parts Control Center, for example, devote less than one percent of their capacity to this function. Even allowing that such a group may be working below capacity, it is clear that it must have significant additional functions which in the short run can be dropped to handle requisitions but which in the long run must be executed if requisition processing is to continue successfully.

One way to model requisition processing by a multi-function server is to allocate a certain fraction of the server's time to requisition processing and calculate the server's capacity in this fraction of total time. This approach may be satisfactory for limited modelling objectives but basically begs the question, because a primary objective of the S^4 computer programs is to help inquire into how resources might better be allocated.

A more general and more satisfactory approach might be to model (simulatively or analytically) all the functions personnel connected with requisition processing are required to perform. This implies modelling all or at least a large part of the workforce in an organization and constructing very involved priority rules to represent the order in which competing functions are executed.

Whatever the most practical solution, future researchers in this area should be forewarned that only quite sophisticated and possibly now unknown analytic techniques will yield useful results.

Q. Organizational Location of Requisitions and Material

It is clear from the description of the support system in Chapter III that requisitions and material frequently flow from one organization to another in the course of being satisfied.

Except in the simplest of paths, it is difficult to estimate by inspection the fraction of time a requisition is lodged in each organization. Table VII-4 displays the results of exact calculation for two commodities - Navy managed electronic parts and DSA managed general supplies. Shown at the bottom of the table is the average time to satisfy a requisition given that it is satisfied at the echelon shown at the top of the table. Since all requisitions satisfied in one of the first four echelons move through the same organizations, these echelons are listed only once.

As might be inferred from data previously presented, satisfaction of a requirement from shipboard stock is one to two orders of magnitude faster than satisfaction from screening, the AFS, Norfolk, or elsewhere in the system. (The last three of these sources show remarkably similar throughput times.) Backordering and spot-buying are almost another order of magnitude slower than immediate issue from somewhere in the support system. Fortunately, these modes of satisfaction are employed for only a small fraction of all end-use requisitions.

A change in percentage for an organization from echelon to echelon is sometimes partly or totally due to the change in time spent in other organizations rather than a change in the organization of interest. For example, a requisition spends 4 to 5 percent of its time at Norfolk if it is satisfied by referral to another stock point but only 1 percent of its time there if ultimately satisfied by back-order or spot-buy. Despite this, the requisition spends the same number of clock hours at Norfolk in each case.

If all requisitions were transmitted from the Sixth Fleet to Norfolk by electrical means, as is recommeded in the next chapter, there would be two results: (1) the percent of time the U.S. Postal Service handles the item as a requisition would drop to zero and (2) the percentage of time spent in fleet communication would more than double. If the recommendation to use MAC exclusively on the Norfolk - Mediterranean run were adopted, the percent of time the material is in the U.S.P.S. would diminish drastically; MAC time would rise several-fold.

R. Evaluating Alternative Proposals

Several of the experiments described in Chapter VI and some of the discussions in this chapter led to conclusion that response time could be reduced by investing or expending funds or that costs could be reduced by sacrificing a greater or lesser amount of requisition response time. The results of many of the experiments and discussions are summarized in Table VII-5. A negative cost signifies a net dollar saving resulting from the proposal; a negative benefit indicates an increase in requisition response time.

DISTRIBUTION OF REQUISITION AND MATERIAL PROCESSING TIME BY ORGANIZATION

ORGANIZATION	COGS 1N AND 9G				COG 1N			COG 9G		
	Ship	MLSF	Screen	Norfolk	Refer	Backorder	Spot-Buy	Refer	Backorder	Spot-Buy
FLEET										
Ship	100.0%	6%	9%	6%	5%	1%	+ %	4%	1%	1%
Communication		8	13	4	3	1	+	3	1	1
Transportation			57	16	13	2	1	10	3	2
AFS/Other		87	21							
NAVY SHORE ESTAB.										
NSC, Norfolk				7	5	1	1	4	1	1
ICP					11@	2@	51			
Other Stock Point					6	1				
QUICKTRANS					1	+	+			
DEPT. OF DEFENSE										
MAC				6	3	+	+	2	1	0
AUTODIN					5	1	+	4	1	1
DSC-Depot								13	4	42*
CIVILIAN										
U.S. Postal Service (Reqn.)				22	18	3	2	15	4	3
U.S. Postal Service (Material)				39	32	5	3	44	13	8
Air Freight								1	0	0
Manufacturer						85	41		71	42*
TOTAL	0.24 da	16 da	10 da	16 da	19 da	130 da	205 da	23 da	79 da	129 da

@Estimated
*Total procurement leadtime divided equally between DSA and vendor in accordance with <u>observed</u> split of ESO procurement leadtime.
Percentages may not add to 100 due to rounding.
+Indicates percent was positive but less than one half.

TABLE VII-4

The last column of the table contains the cost (or saving) per hundred of a day benefit (or malificence). If all the values in the last column were accurate and comparable, one would want to implement first either that proposal showing the largest negative value, if total costs are to be reduced, or that proposal showing the smallest positive value, if funds are available for making performance improvements. This process should be continued for successive proposals meeting one of the above criteria until necessary cost reductions have been made or additional funds have been completely spent. (The one exception to this is shipment via MAC from Norfolk, which saves money but does not increase response time.)

For several reasons the data in Table VII-5 should not be used in their present form as the sole basis for decision making. Aside from the obvious issues of arithmetic errors, incomplete data, and difficulties in combining investment and expense costs, there are two major factors that should be carefully evaluated -- spillover effects and incomparability.

Spillover effects can be further divided into those that might reasonably be assessed by study group personnel and those that are beyond their special competence to calculate. For example, in computing the net savings in Experiment 5, it was assumed that DSA's processing costs are identical to those at NSC, Norfolk. Any difference in costs could be uncovered with slight additional effort and included in the net-cost calculation.

As a second example, consider the cost of building, installing, and operating the overseas AUTODIN transmission system discussed in Section VII D. Some of the benefits were enumerated there; additional benefits (such as status reporting) might have been uncovered by the study group. But there are still further potential benefits (such as personnel strength reporting) that could be evaluated by those with the appropriate knowledge and experience. On the other hand, the cost of the proposal can be reckoned only by the engineers and economists in NAVELEX and NAVSHIPS.

Still other external effects are peculiarly military and can be assessed only by those with the requisite Naval operating experience. A prime example of this is the experiment (number 11) which assumes elimination of the AFS support in the Sixth Fleet. Undoubtedly more important than the marginal savings displayed in the last column of Table VII-5 are the wartime consequences of the proposal. What effect will lack of an AFS have on the ability of a task force to remian at sea or to perform its primary and secondary missions? How much less time can it spend in the open sea? How does reduced flexibility and increased time in port influence its capacity to perform offensive maneuvers or defend sea lanes? Are there any satisfactory and economical ways to compensate for the lack of an AFS? These and many other questions can and must be addressed by persons

EFFECT OF PROPOSALS FOR CHANGING RESPONSE TIME

REFERENCE	PROPOSAL	ANNUAL COST ($000)*	BENEFIT (DAYS)@	COST PER .01 DAY
Experiment 1	Remove TORs from COSAL	- 563	- 0.15	- $37,530
Experiment 4	Eliminate MATCONOFF and			
	(1) keep Norfolk availability constant	- 50	- 0.45	- 1,111
	(2) raise Norfolk availability	?	- 0.27	?
Experiment 5	Close NSC Norfolk			
	(1) and send inventory to DSA	- 1,185	- 0.39	- 30,380
	(2) and eat-down inventory	- 10,385	- 0.88	- 118,000
	(3) to Sixth Fleet only	- 33	- 0.88	- 375
Experiment 7	Reduce wholesale range			
	(1) of 1H items	- 6,605	- 2.37	- 27,870
	(2) of 2N items	- 1,804	- 22.36	- 806
Experiment 8	Change wholesale stock depth			
	(1) decrease 1H	- 2,500	- 1.63	- 15,300
	(2) increase 4N	2,050	+ 0.47	+ 43,600
	(3) decrease 4N	- 570	- 2.32	- 2,460
Experiment 10	Reduce COSAL endurance to			
	(1) 60 days	- 553	- 0.6	- 9,200
	(2) 30 days	- 1,474	- 1.7	- 8,670
Experiment 11	Eliminate AFS function and			
	(1) save 1 AFS	- 10,700	- 3.8	- 28,150
	(2) save 3 AFSs	- 32,000	- 3.8	- 84,200
Experiment 19	Increase NSC Norfolk staffing 10% selectively	+ 440	+ .0005	+ #
Experiment 20	(1) Resupply ships by air	+ 243	?	?
	(2) Carry complete FILL at Norfolk	+ 167	?	?
Section VII D	Install AUTODIN in Sixth Fleet Ships	?	+ 0.38	?
Section VII E	Computer process IPG II requisitions at Norfolk more frequently	+ 19	+ 0.02	+ 9,500
Section VII J	Use MAC from Norfolk	- 84	0	---
Section VII J	Use MOM from Oakland	- 46	- .04	- 11,500

* a + signifies cost, a - savings; # reduction cannot be achieved; @ a + signifies decreased time, a - increased time

TABLE VII-5

with Naval operating experience before a judgement can be made on this issue.

Incomparability, in this study, refers to the fact that not all experiments and discussions cover the same geography or the same commodities. All benefits (or disbenefits) are described in terms of the effect on the Sixth Fleet. However, not all experiments are limited in their effects to the Sixth Fleet. Experiments 4, 11, and 20 and the discussion in Section VII J apply strictly to the Sixth Fleet. But the costs of shipboard AUTODIN installation cannot be limited to the Sixth Fleet (even though the benefits may accrue primarily to that Fleet) because ships are constantly shifting between the Second and Sixth Fleets. Conversely, by the very way in which Coordinated Shipboard Allowance Lists are now designed, it would not be possible to restrict the cost reductions inherent in Experiments 1 and 10 to the Sixth Fleet.

Experiments 5, 7 and 8 present another sort of incomparibility. Closing NSC, Norfolk, would work to the detriment not only of the Sixth Fleet but to three other classes of customers as well - the Second Fleet, the Atlantic Fleet installations ashore (such as air stations), and the Shore Establishment activities served by Norfolk. Changing the range or depth of a given cognizance symbol of material would have Navy-wide impact, but not for all items. The deterioriation in service for 2N cog items, although world-wide and severe, might not influence equipment operation significantly if 2N items are very seldom needed in shipboard repair.

By extending the scope of analysis and redefining benefits, incomparability of the kind described here can be overcome. The first step is to estimate the consequences of a proposed course of action on all Navy customers and the total differential cost DOD-wide. Then convert days of change in average response time to requisition-days saved or spent per annum. In this way two proposals having impacts in different parts of the Navy can be compared, if one is willing to accept the assumption that one requisition-day saved is as important as another.

Despite these problems, some of which can be resolved by further analysis, others by the application of outside experience, results of the sort portrayed in Table VII-5 represent a first step in providing a foundation of basic organized data on which the Navy decision maker can build informed judgements.

VIII. RECOMMENDATIONS

In light of the facts and discussion in previous chapters of this report, it is recommended that:

Recommendation 1 - OPNAV incorporate available S^4 models and programs into evaluation of current Sixth Fleet surface support policy and into testing possible revisions to existing policy in the S^4 simulators.

Recommendation 2 - CNM provide CNO a Plan of Action and Milestones for extending S^4 models and programs to (1) Seventh Fleet surface support, (2) deployed aircraft support, and (3) CONUS support and (4) maintain the models and data base current. (Section VII-A applies).

Recommendation 3 - OPNAV provide for continuing review of existing logistic support policy, and new programs and policies having potential budget impact, through use of S^4 models, programs and simulators by testing and predicting the consequences of same. (Section VII-B applies).

Recommendation 4 - NAVMAT determine the feasibility of using S^4 models to project, during the development of major weapons systems, the consequences, in terms of mean supply response time and operational availability, of alternative proposals for the design, maintenance and supply support of the system and provide these data to ILS managers for consideration in developing supply support policies. (Section VII-C applies).

Recommendation 5 - As a first step in isolating possible causes of low operational availability, NAVMAT direct (1) the Naval Ships Engineering Center to compute, for all major equipments in a "trouble" status, the equipment's MTBF (mean time between failure) and MTTR (mean time to repair) and (2) the Fleet Material Support Office to compute the MSRT (mean supply response time). (Sections VI-A2 and VII-C apply).

Recommendation 6 - NAVMAT act expeditiously to develop the proposed plan for installation of digital data communication capability aboard CV, LPH, AFS, AD and AR class ships per CNO letter serial 941C/2564 of 30 May 1973. (Section VII-D applies).

Recommendation 7 - CNO reemphasize the requirement that all IPG I and II requisitions for submission to CONUS be sent by electrical transmission unless (1) operational restrictions prevent sending messages or (2) material is to be used by ship upon return to CONUS. (Section VII-D applies).

Recommendation 8 - CNO reemphasize the requirement that all IPG I and II requisitions clear the requesting ship 48 hours after the demand arises and clear the communications system 12 hours after entry into the system. (Section VII-D applies.

Recommendation 9 - NAVSUP direct CONUS supply centers to enter IPG II Fleet requisitions on essentially the same schedule as IPG I requisitions, at least to determine status and to refer to ICP/DSC. (Section VII-E applies).

Recommendation 10 - NAVSUP direct CONUS supply centers to investigate representative cases in which IPG I and II requisitions require more than 48 hours for initial processing into the computer and take or propose necessary systemic action to avoid such delays. (Section VII-D applies).

Recommendation 11 - NAVSUP direct NSC, Norfolk to ship all IPG I and II material destined for the Sixth Fleet via Military Airlift Command scheduled flights, provided that periodic analysis of receipt data reported by computerized ships as described in Section VII-O or equivalent data indicates that delivery to ship via MAC is as rapid as delivery via Air Parcel Post. (Sections VII-J and VII-O apply).

Recommendation 12 - NAVSUP direct NSC, Oakland to ship all IPG I and II material destined for the Sixth Fleet by Military Ordinary Mail provided that periodic analysis of receipt data reported by computerized ships as described in Section VII-O, or equivalent data indicates that Military Ordinary Mail continues to enjoy priority treatment within CONUS. (Sections VII-J and VII-O apply).

Recommendation 13 - Whenever possible, NAVSUP develop and promulgate rules for use by Navy shippers that will insure responsive transportation service at least cost; where specific rules cannot be developed NAVSUP promulgate policies, guidelines, and direction to all Navy shippers to analyze shipping destinations and transportation rates with a view to purchasing the cheapest responsive transportation service. (Section VII-J applies).

Recommendation 14 - CNM investigate modification of 3-M data collection system for ships to collect information on delays due to ships operation and outside assistance (e.g., IMA or Tech. Assistance) and, if feasible, undertake collection. (Sections VI-A2 and VII-M apply).

Recommendation 15 - To prevent distortion in measuring operational availability of shipboard equipment, NAVMAT establish a single standard method for measuring time in computing mean time between failures, mean time to repair, and mean supply response time. (Section VII-N applies).

Recommendation 16 - NAVMAT investigate the causes of serial requisitioning, especially those related to fault isolation, and develop methods, procedures, or programs for reducing serial requisitioning. (Section VII-I applies).

APPENDIX A

STUDY DIRECTIVE OF 31 AUGUST 1971

MODIFICATION OF 27 MARCH 1972

EXTENSION OF 18 JANUARY 1973

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

IN REPLY REFER TO
OP-96/vpo
Ser 397P96
31 AUG 1971

From: Chief Of Naval Operations
To: Distribution List

Subj: Study Directive for Ship Supply Support Study

Ref: (a) OPNAVINST 3501.4 of 29 May 1969, "Navy Readiness Analysis System (NRAS)"

Encl: (1) Estimating the Effect of Supply Support on Mission Readiness
(2) Use of Realistic Factors in Study
(3) Manning Requirements
(4) Guidance Concerning Approved Threat and Study Assumptions

1. Title. Ships Supply Support Study (S^4).

2. Type. CNO in-house Study.

3. Background. There now exists no way of describing the relationship between the budget dollars allocated to supply support and supply support effectiveness that is indicative of the material condition of the fleets and is a measure of the capability of the fleets to implement the strategy as set forth by the President and the National Security Council. Numerous studies have attempted to develop a meaningful measure of supply support readiness that would be a part of an effective means of managing supply support from the CNO level. There have been developed several "supply effectiveness" procedures intended to measure specific aspects of internal supply system efficiency, i.e., percentage of total requisitions satisfied, percentage of items demanded actually onboard, Consolidated Shipboard Allowance List (COSAL) effectiveness. Measures of this sort do not provide the CNO with the criteria required for efficient allocation of budget dollars to supply support.

4. Objective. This study will define, develop, and propose an automated model by which supply support dollar outlays may be related to fleet capability. The main product of the study should be a mechanism for periodically reporting to the CNO the readiness of fleet units (from a supply support standpoint) and the monetary expenditures required to maintain or adjust these levels of readiness. The method should be capable of predicting the effect on availability of

varying supply support expenditures, including expenditures for material, depot repair, transportation, personnel, and computers.

5. Specific Guidance. The study will first undertake a review of all existing data reporting and material management systems. The need for a new data reporting system is doubtful. Rather, an effort should be made to use the profusion of data now in existence. The study should look at efforts such as the Navy Readiness Analysis System, reference (a). The material presented in enclosure (1) is an attempt to provide a conceptual view of readiness and its relation to supply availability, throughput times, and attendant costs. The study group should attempt to keep its results on the simplest level possible. Although material readiness is a very complex function of many variables, a clearly understood, relatively simple measure of output is critical to fiscal management of supply support. The scope of this study will be limited to General Purpose Forces (excluding aviation). In order to provide the decision-makers with quantitative analytical rationale with which they may select the most effective and efficient options, it is imperative that:

a. Assumptions necessary to structure the analysis be clearly identified (the Study Project Officers Handbook stipulates that assumptions should be clearly stated in a separate paragraph at the beginning of the report. Further, those assumptions which are applicable should be restated at the beginning of each chapter, annex or appendix of the report).

b. Sensitivity checks and uncertainty analyses will be conducted for assumptions in general conformity to the guidance contained in enclosure (4).

c. Strong emphasis be placed upon specifying a realistic threat as discussed in enclosures (2) and (4).

d. The study report include an appendix that will describe mathematical or simulation models used for the study in terms that would provide a clear and concise description of the fundamental workings of each model or simulator. This description should explain in qualitative terms (logic diagram) the general methodology. Upon request, the detailed analysis will be made available for review.

6. Purpose. The output of this study will be a procedure or set of procedures that can be employed annually by the Navy as part of the Planning-Programming-Budgeting System (PPBS) to justify and allocate budget dollars to supply support. It is expected that this study will result in a new OPNAV directive for the management of secondary items which will be a useful tool for supply support management.

7. Coordination.

a. The Study Sponsor is the Deputy Chief of Naval Operations (Logistics).

b. CAPT W. J. McCLAREN, OP-412, is designated the CNO Project Officer and is responsible for compliance with current instruction on the CNO Studies and Analyses Program and the guidance contained in enclosure (2).

c. An Advisory Committee will be established with the Director, Material Division, OP-41, Chairman- and the following members or their designated representatives: OP's -- 02, 03, 05, 90, 96; NAVSUPSYSCOM, NAVMAT, and CNA.

d. CDR M. K. SHIPLEY SC, USN, OP-964C, is designated the OP-96 Study Monitor.

e. Manning requirements for this study are contained in enclosure (3).

f. The Director, Systems Analysis Division is directed to conduct a series of technical reviews of this study during its progress. The purpose of these reviews is to evaluate the validity of the study approach and the quality of the analyses. The results of each review shall be promulgated to the members of the Advisory Committee and the Study Project Officer.

8. Reporting.

a. The Study Plan will be submitted to the Advisory Committee for review and approval within four weeks from date of this Directive. Upon approval by the Chairman, copies of the Study Plan will be forwarded to the VCNO, DNPP, CNM, and COMNAVSUPSYSCOM for information. Study progress should not be delayed pending approval of the Study Plan.

b. Monthly reports will be submitted to OP-96 in accordance with current instructions.

c. The study effort will be divided into four phases:

PHASE I - Review and critique of existing models and data systems.

PHASE II - Preliminary design and laboratory testing of the procedure for a limited range of material.

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Ser 397P96

PHASE III - Final design and testing of the procedure on a full scale basis.

PHASE IV - Preparation of production computer programs; establishment of data input files, and documentation of operating procedures.

d. Study reports shall be submitted as follows:

(1) Working Papers to Advisory Committee as available.

(2) Interim Report to Advisory Committee by 1 Jan 1972.

(3) Final Report to the CNO by 15 August 1972.

(4) Operating System to be turned over to executive agent by 10 March 1973.

... H. BAGLEY
...ector, Navy
...ram Planning

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ESTIMATING THE EFFECT OF SUPPLY SUPPORT

ON MISSION READINESS

The influence on ship, task force, or fleet readiness of specified levels of supply support can be estimated by combining the results of subordinate analyses and simulations which investigate successively finer details about the performance of the supply system. This paper broadly describes these analyses and suggests how they might be combined to provide overall estimates of readiness.

In general four analyses are required to estimate the effects of supply on mission readiness. In increasing level of detail, these are:

1. Evaluating the ability of a task force or fleet to perform its mission given the overall performance of individual weapons systems or ships and the relative importance of each weapon system or ship to the completion of the mission.

2. Estimating overall weapon system or ship effectiveness as a function of operational availability assuming other factors are held constant.

3. Computing operational availability -- the ratio of uptime to total time -- as a function of mean time to supply material to shipboard users.

4. Quantifying mean supply response time (MSRT) on the basis of supply availability and throughput time at each echelon in the supply system. Subordinate analyses must be conducted or observations made to estimate supply availability and delay times. Each of these analyses are outlined below. The first two analyses are involved with the weapon's operation while the latter two deal with the supply aspect of the problem. It is considered feasible to pursue effort along both lines simultaneously and independently. Prior to exercising the procedure, a suitable interfacing of the two basic parts must be made.

MISSION PERFORMANCE ABILITY

The ability of a task force or fleet to perform its missions can be evaluated by a series of simulations which would consider the various threats facing a task force, the probability of their occurrence, and the chances of successful U. S. Navy response, given the performance states of individual weapon systems or ships.

WEAPON SYSTEM EFFECTIVENESS

The effectiveness of a weapon system is a function of 3 variables*:

Its performance -- whether it flies at Mach 1 or Mach 2, whether it hits within 50 or 500 feet of a target,

its utilization -- the extent to which it will be employed, assuming it is functioning properly, and

its availability -- the fraction of time the weapon will be "up" -- that is, functioning, ready for use.

Because the supply system cannot in any way affect the performance or the utilization of a weapon system, these two variables are assumed to be fixed. Values of these variables should be set at currently observed figures and the remaining variable -- availability -- adjusted to yield the minimum weapon system effectiveness necessary to complete the missions simulated in the first analysis described above.

OPERATIONAL AVAILABILITY

The factor of operational availability needed to evaluate weapon system effectiveness is simply the ratio of system uptime to total elapsed time. Operational availability (A_O) can be more precisely defined by the following expression:

$$A_O = \frac{MTBF}{MTBF + MRT + MADT + MSRT}$$

where:

MTBF = mean time between failures (the average time elapsing between the start-up of an equipment and its next failure).

---

* See Navy Systems Performance Effectiveness Manual, NAVMAT P-3941A; Headquarters Naval Material Command, Washington, D. C., 1 July 1968; pp B6-B10.

MRT = mean repair time (the time a mechanic or technician spends actively repairing the equipment).

MADT = mean administrative delay time (the average time a repair is delayed for administrative reasons. These delays are of three kinds- delays in getting repair personnel and equipment to the repair site, waiting for outside assistance to complete repairs, and delays due to ship's operations).

MSRT = mean supply response time (the average time the supply system requires to get needed parts and components to the repair site).

It should be noted that the factors determining operational availability need not be single valued. Thus, it will very likely be appropriate and economically feasible to use one value of MRT characteristic of electronic gear and a quite different value in estimating the availability of hull, mechanical, and electrical equipment. It is even possible to observe or estimate average values or a distribution of values for individual equipments, although this would probably be prohibitively expensive.

For purposes of the Ships Supply Support Study values of MTBF, MRT, and MADT will be assumed to be fixed by external conditions. It should be observed that these too can be varied so as to estimate the relative gains per dollar of expenditure to be achieved by decreasing MSRT or by reducing MRT and MADT (i.e., by increasing the numbers and skills of shipboard mechanics or by improving the maintainability of the system) or by increasing MTBF (i.e., by enchancing the achieved reliability of the equipment).

MEAN SUPPLY RESPONSE TIME

Mean supply response time (the single variable in the expression for operational availability to be exercised in this study), is, in turn, a function of the supply availability at each echelon in the supply system (including the ship's storeroom) and the time required, to satisfy an end use requisition. The expression for mean supply response time is:

$$MSRT = a_1 t_1 + (1-a_1) a_2 t_2 + \ldots + a_j t_j \prod_{i=1}^{j-1} (1-a_i)$$

where: a_i = the probability that the ith echelon will satisfy an end-use requisition not satisfied by a lower numbered echelon.

t_i = the time elapsing from mechanic's stated need for material until the mechanic receives material from the ith echelon.

The MSRT (and hence the operational availability) associated with a given level of investment and expenditure can be estimated if functional relationships can be constructed between money spent at a given supply echelon and the resulting availability (a_i) and processing and transportation delay (t_i).

Several inventory analyzers and simulators have been developed which will accurately relate levels of inventory investment in dollars to the probability that a requisition will be satisfied. Some simulators even account for rationing among multiple claimants for a single item.

It is possible to collect data on the costs and speeds of various modes of transportation and communication. Furthermore, one can observe current values of salaries for operating personnel and of computer rentals and the associated requisition and material throughput times. In very simple cases, the effect on throughput (i.e., delay) types of changes in numbers of operating personnel and computer capacity can be deduced analytically; in the complex situations characteristic of the Navy supply system, simulation techniques should be used.

First priority and major effort will be given to the third and fourth major analyses described above. This will result in the development of a model which relates funds spent for various supply purposes at various levels to the operational availability of individual weapons systems. If the weapons systems essential to the completion of a mission can be enumerated and if these systems can be assumed to be either in an operative or totally inoperative state, then the ship's effectiveness in support of a mission can be estimated.

MEMORANDUM FOR CNO PROJECT OFFICER FOR SHIPS SUPPLY SUPPORT STUDY

Subj: "Use of Realistic Factors"

1. The use of realistic factors in studies and the mechanism for ensuring such realism are areas of concern to the CNO which must be properly managed to produce credible study results. The Study Sponsor and Project Officer have a primary responsibility for injecting operational and technical realism and sound judgment into every facet of the study effort. Matters to which attention should be devoted to achieve the degree of realism expected should include but not be limited to the composition of the Study Group, the development of the Study Directive, a comprehensive Study Plan, the threat analysis, the process of selection and validation of performance factors, effectiveness criteria, numerical data and study results.

2. The objective of this study is to provide the CNO and SECNAV with analytical insights into the merits of alternative courses of action, as a basis for decisions in which operational experience and judgemental factors have been incorporated. The development and presentation of findings must provide for the incorporation of these factors.

a. Criteria of effectiveness must consider the diversity of unpredictable situations in which forces may have to operate. A scenario is a useful tool for quantitiative analysis, but no single scenario can reflect this diversity. Even when multiple scenarios are used, measures which provide the operational commander with additional margins of flexibility against the unpredictable must be developed.

b. Criteria of effectiveness must not be limited to those for which hard quantitative measures can be assigned. Efforts must be made to assign effectiveness for deterrent or other peacekeeping roles in which the output is difficult to quantify, or alternatively to note the existence and prospective importance of these roles in making a final decision on forces.

c. The study should reflect the understanding that for many military tasks, in war or peace, timeliness of response and/or concentration, as well as other qualitative values (such as covert or uncommitted response, retractability, and

ENCLOSURE (2)

political flexibility) may be critical factors in determining effectiveness.

3. The initial study efforts of the study group should be devoted to the collection and formulation of such realistic factors and inputs for the structuring of the study base case. Realistic factors and inputs must include:

a. Scenario - What is basis? Is it reasonable, viable, and supported by war plans (cite plans)? Are multiple scenarios considered? Are national objectives identified and supported.

b. Threat - What is basis? Is it realistic and supported by approved intelligence (cite supporting justification)?

c. Own Forces - Relate to force documents (JSOP, PO, FYDP, etc.). Deploy and employ in accordance with OP Plans (cite plans). Are other services forces and systems required as inputs?

d. Allies and Basis - Are Alliances and base rights viable (cite justification)? How do we degrade our employment and performance for realistic loss of Allies and bases?

e. Own and Enemy Weapons - Are current and predicted performance factors realistic, related to historical experience, and validated? What R&D factors and programs are addressed (state-of-art or breakthrough of weapon systems)?

f. Own Tactics - Are tactics employed validated by Fleet doctrine and appropriate publications? How is it envisioned that tactics will be varied with dynamics of situation and engagement?

g. Enemy Tactics - Are they reasonable, realistic and supported by intelligence? What are enemy capabilities? Has enemy Order-of-Battle been examined?

h. Effectiveness Criteria - What are various alternatives? Have multi-mission roles been evaluated? Are effectiveness measures directly related to mission(s)? Are measures reasonable, related and supportable? Are measures being addressed relative or absolute?

i. Costing - Current DOD program cost factors must be used! Costs not directly associated with FYDP must be identified (Ex: foreign base costs, lease rights, nuclear war heads, etc.).

j. Numerical Data - Is numerical data accurate and consistent for and from all Naval sources? Are there discrepancies (identify)? Are the data credible? Has OP-03 concurred in ship force levels numerical data? Has OP-05 concurred in aircraft levels numerical data? If no cognizant office has responsibility for numerical data, get OP-90A to provide or refer you to appropriate office.

4. It is recognized that varying degrees of confidence will exist in the base case factors and inputs and that there may be wide ranges of uncertainties in some of those factors. The important consideration is that the degree of confidence is noted and in particular that uncertainties are highlighted. Such uncertainties should then be made candidates for parameterization and a rationale for the range to be tested should be provided.

5. Of special importance is that the Project Officer understand the significance of the periodic briefings for the Advisory Committee, and in particular, of the initial briefing for that group. It is expected that at an early briefing(s) the Project Officer will present base case factors and inputs for the consideration and acceptance of the Advisory Committee prior to the commencement of study analysis and production of study results. Although the staffing and administrative preparations for these briefings must be thorough, the message which must get through to the Advisory Committee concerns the character and depth of the operational realism which is reflected in those preparations, and the confidence that such realism will be reflected in the study results.

MANNING REQUIREMENTS FOR

SHIPS' SUPPLY SUPPORT STUDY

COMMAND	RANK	NO	DURATION	SPECIALTY
OP-41	CAPT	1	Part Time	CNO Project Officer
OP-02	CDR/CAPT	1	Part Time	Weapon System Mission Importance
OP-03	CDR/CAPT	1	Part Time	Weapon System Mission Importance
CNM	CDR/GS-14	1	Consultant	Study Design
ONR	GS-15	2	Consultant	Study Design Theoretical Assistance (Participation to be requested of ONR)
NAVSUPSYSCOM				
(06)	GS-15	1	Full Time	Assistant to Project Officer (Study Director)
(06)	GS-14	1	Part Time	Technical Assistance Study Design
(06)	GS-5/6	1	Part Time	Secretary
(06)	LT	1	Part Time	Technical Assistance
(01)	GS-13/14	2	Part Time	Budgeting and Statistics
(06)	LCDR/GS-13	1	Part Time	Fleet Liaison
(04)	LCDR/GS-13	1	Part Time	Financial Management
(04)	LCDR/GS-13	1	Part Time	Allowance and Load Design
(04)	LCDR/GS-13	1	Part Time	Activity Management

(04)	LCDR/GS-13	1	Part Time	Distribution System Design
FMSO	LCDR	1	Part Time	Technical Director For Analysis
	GS-13/14	1	Part Time	Chief Operations Analyst
	GS-13/14	1	Part Time	Chief Computer Analyst
	GS-9/12	2	Full Time	Operations Analyst
	GS-9/12	3	Full Time	Computer Analyst
	GS-3/5	1	Part Time	Secretarial
MSO	GS-11/14	1	Full Time	Operations Analyst
	GS-11/14	1	Full Time	Computer Analyst
	GS-11/14	1	Full Time	Programmer
	GS-11/14	1	Part Time	Statistician
	GS-3/5	1	Part Time	Secretary
ESO	GS-9/12 LT/CDR	1	Part Time	Liaison Officer
SPCC	GS-9/12 LT/CDR	1	Part Time	Liaison Officer
NSC NORVA	GS-9/12 LT/CDR	1	Part Time	Liaison Officer

Guidance Concerning Approved
Threat and Study Assumptions

1. Analysis should be presented in terms of approved threat (NIPP year) and NIES. Threat variations are permitted and encouraged in order to identify the sensitivity of system effectiveness to threat estimates and projections. However, any assumptions which constitute excursions from the base-line intelligence estimates must be clearly identified and documented.

2. Whenever possible the effects of relaxing the assumptions should be identified. Uncertainties as far as threat, technical, cost and operational parameters should be explored in reasonable ranges to identify the sensitivity of the study results to such uncertainties. While a certain amount of judgment is required to identify key parameters, the range of uncertainty needs to be explored and addressed in the report.

It is generally useful to begin the analysis with the best estimates available and to introduce variations, pessimistic on lower limits and optimistic on upper limits to identify the effects of uncertainty on various parameters.

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

IN REPLY REFER TO
OP-412/ipl
Ser 512P41

From: Chief of Naval Operations
To: Distribution List

Subj: Modification of Study Directive for Ships Supply Support Study

Ref: (a) CNO ltr OP-96/vpo ser 397P96 of 31 Aug 1971

1. Paragraph 8d of reference (a) is revised as follows:

"d. Study reports shall be sumbitted as follows:

(1) Working Papers to Advisory Committee as available.

(2) First Interim Report to Advisory Committee by 1 January 1972.

(3) Second Interim Report to Advisory Committee by 15 August 1972.

(4) Final Report to the CNO by 1 March 1973.

(5) Operating System to be turned over to Executive Agent by 10 March 1973."

2. The designation of the 15 August 1972 report has been changed from "Final Report to the CNO" to "Second Interim Report to the Advisory Committee." The "Final Report to the CNO" has been shifted to 1 March 1973, consistent with turnover of the operating system to the Executive Agent which remains as originally scheduled for 10 March 1973. This change is made to permit a more comprehensive and useful final report.

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President CNA	OP-943G	

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

IN REPLY REFER TO

OP-96/sjg
Ser 69P96
JAN 18 1973

MEMORANDUM FOR THE DIRECTOR, MATERIAL SUPPORT DIVISION

Subj: Ships Supply Support Study (S^4); extension of

Ref: (a) OP-412 Memo Ser 63P41 of 12 Jan 73 (NOTAL)

1. As requested by reference (a), the Ships Supply Support Study (S^4) is extended until 31 May 1973 with an interim report to be submitted on 9 March 1973. Additional funds in the amount of $19,500 will be allotted to the study as required.

M. R. HOLCOMB
Deputy Director
Systems Analysis Division

Copy to:
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APPENDIX B

STUDY PLAN

SHIPS SUPPLY SUPPORT STUDY (S^4)

1. OBJECTIVE

a. As stated in the study directive, the objective of the study is to "define, develop, and propose an automated method by which supply support dollar outlays may be related to fleet capability". The objective will be achieved through two supply system simulators. The first of these will relate material investments at each of several supply levels (or echelons) to the time required to put material in the hands of an end-user. The second will indicate the influence of both stock investment and funds spent for computers, personnel, materials handling equipment, communication and transportation, on three output measures -- requisition response time, supply response time, and equipment availability. The simulators will be designed in such a fashion as to show the effect of specific changes in the level of material and operating budgets on the three output measures.

b. Each of the two supply system simulators, once designed, built, and provided with input data, can be used as a laboratory in which experiments can be cheaply performed to test hypotheses about the supply system. The inputs to the simulators will be data about the material demands placed on the various echelons of the supply system and the resources available to process these demands (or the performance of each echelon in meeting the demands). The output from the first simulator will be requisition response time - the time from the expression of an individual requirement aboard ship until the material is placed in the hands of the mechanic. The second, or advanced, version of the simulator will display (in addition to requisition response time) (1) supply response time (i.e., - the delay to a repair resulting from lack of parts, and (2) the operational availability of an equipment or weapon system. If the inputs to the simulators are manipulated by changing supply performance and throughput times or by altering resources available for supply functions, the outputs of the simulators will answer many interesting "what would happen if" questions. Possible "what if" questions are:

(1) What would happen to requisition response time (or

operational availability) if the depth of each item in the Consolidated Shipboard Allowance List (COSAL) were cut by a specified percent?

(2) What would happen if the mobile logistics support force were relieved of all its end-use requisition processing functions?

(3) What would happen if all requisitions for material managed by the Defense Supply Agency were submitted directly from the ship to the appropriate Defense Supply Center?

(4) What would happen if the stock range in the COSAL were increased 25 percent?

(5) What would happen if the staffs at Naval Supply Centers were permanently increased by 500 personnel? Would this cost more or less, in the long run, than (5) above?

(7) If requisition response time were cut in half, how much would operational availability be increased?

2. SCOPE AND DEPTH

a. The study will address all General Purpose Forces, except Aviation. Both to simplify administrative and data collection problems and to demonstrate the feasibility of making forecasts covering a subset of the entire Navy, the locus of the study will be the Sixth Fleet and its organic and external supply support. Further to simplify data collection problems and reduce computer running time, some ships of the Sixth Fleet may need to be excluded from analysis; those that are analyzed will be selected in such a manner as to be representative of the entire fleet. However, the simulators will be designed so that data from another Fleet or the Navy as a whole can easily be substituted.

b. The supply of both NSA and APA material will be analyzed in the study. However, ammunition, fuel, aviation parts and components, personnel related items and housekeeping supplies will not be considered.

c. The study will not look at trade-offs between supply and the other factors of production that produce ready ships. Thus the effects on ship readiness of more (or less) supply vs. more redundancy vs. higher reliability and maintainability vs. more maintenance will not be addressed. However, the data and conclusions produced by this study will provide useful inputs to these other trade-off studies.

3. SPECIFIC GUIDANCE AND ASSUMPTIONS

a. The study will assume that the external environment in which the Navy operates and the internal structure of the Navy remain essentially constant. In particular, it will be assumed that a peace-time-cold-war situation exists, that the supply characteristics of Navy ships remain essentially unchanged and that current maintenance policies will remain in force.

b. It will be assumed that second order effects can be ignored. For example the reduction in the time to issue a component to a ship as a result of reducing the issue time for a piece part to a depot level repair activity will be assumed to be insignificant.

c. With respect to the first simulator it will be assumed that requisition response time is an adequate measure of supply performance. This implies that being without a single part in 10 different equipments for a month is equivalent to being without 10 different parts in 1 equipment for a month. It also implies that being without parts a, b, c, and d is equivalent to being without parts e, f, g, and h for the same length of time. Finally, it implies that a part missing from a given equipment has as serious an effect as the same part missing the same length of time from any other equipment.

d. The simulators described in paragraph five will be designed in such a way as to simplify maintenance in both program logic and input data.

e. The major assumptions on which the simulator designs are based will be clearly identified in the Technical Memoranda and in the Interim and Final Reports. The major assumptions will be the subject of sensitivity analyses (sub-tasks 5.9, 5.10, and 5.11) the results of which will be included in the Final Report.

4. EFFECTIVENESS CRITERIA

a. The study will forecast the effect on shipboard support of changes in certain portions of NSF, OPN, and SCN budgets. Support effects will be described in terms of requisition response time, supply response time, and operational availability rate, defined in Appendix A. The simulators which form the main body of the study will be so designed as to estimate these three outputs within 10% of their current values when current resources are used as inputs to the simulator.

b. The three outputs will be measured at the shipboard level in terms of average performance over a period of time (e.g., - 90 days). Although no attempt will be made during the course of the study to estimate the essentiality of the equipment supported, provision will be made to weight output measures according to the essentiality of the supported weapon system and ship. Output measures will be aggregated by weapons systems, ship, and fleet. Material inputs will be subdivided by echelon and cognizance symbol of material; other inputs will be subdivided by expending activity and purpose of expenditure (i.e., - computer operation at inventory control points; salaries at supply centers).

5. METHODOLOGY

a. The objectives of this study will be achieved in the main by the development and exercise of two Supply System Simulators - each a combination of several analyzers and simulators * designed to explore the relationships between material and O&MN funds available for various logistics purposes and the response time that can be achieved by these funds. The first will use available products and have a narrow objective, the second will consider a wider spectrum of logistics changes in a more detailed fashion. The second simulator will include a device for estimating operational availability.

b. Several benefits flow from the early construction of an elementary version of the simulator. First, personnel on the study project gain practice in the design, fabrication, and testing of a large scale flow and inventory simulator. Second, production of an operating simulator is the first (but not conclusive) evidence of the feasibility of the advanced verstion. Given that the elementary simulator <u>can</u> be made, its operation will test, and may lead to improvement in, the components that are to be lifted bodily and incorporated into the more sophisticated version. Next, the basic simulator can be used to conduct sensitivity

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*An analyzer evaluates mathematical expressions describing the relationship between input (s) and output (s); a simulator reproduces a stream of events according to specified rules and by tallying results, calculates and displays a possible relationship between inputs and outputs.

studies to determine those features of the advanced simulator that ought to receive the greatest time and attention. Finally, if successful, the first edition of the simulator can be used soon to forecast the consequences of material resource reallocations or augmentations. Indeed, where <u>changes</u> in processing time are not of interest and where requisition response time can be used as a surrogate for supply response time or operational availability, the basic simulator will continue to be useful in resource trade-off analyses.

c. The first (Mark I) version of the Supply System Simulator investigates the gross supply effectiveness* of each supply echelon (or level) as a function of funds available for investment in stock at that echelon. This is done by looking at a representative number of items demanded of representative activities at each echelon. All or any portion of the supported general forces can be investigated. Specifically for S^4, the Sixth Fleet and its supporting echelons will be investigated. Throughput times and gross supply availabilities for each echelon are then combined to produce an estimate of requisition response time.

d. The Mark II version of the Supply System Simulator will refine and extend the Mark I version by linking requisition response time to the operational availability of selected weapons systems, by relating throughput times to processing cost, by including alternate methods for supplying material, by allowing for stock rationing as well as expedited processing, and by modelling the transient responses to changes in the system. Refinements will be accomplished in the priority listed above.

e. The most difficult and time consuming task in the design of Mark II version of the Supply System Simulator involves the modelling of response time as a function of processing resources and their costs -- personnel, computers, materials handling equipment and transportation and communication systems. Only if reasonably realistic modelling can be accomplished in this area will it be possible to assess the consequences of trading-off computers for transportation systems or office personnel for materials handling equipment. In fact, only if the costs of faster processing can be estimated can trade-offs among inventories at different echelons be accurately gauged.

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*Gross supply effectiveness is the ratio of requisitions satisfied from stock at a particular echelon to the requisitions submitted to that echelon.

f. A schematic of the general structure of the Mark I simulator is contained in Chart 1, that of the Mark II simulator in Chart 2. Appendix 1 contains a more complete statement of the methodology than that given here.

6. TASKS AND TASK SCHEDULE

a. The study will be divided into the following nine major tasks:

TASK	DESCRIPTION	COMPLETION WK	COMPLETION DATE
1	Design Mark I simulator	7	20 Aug 71
2	Construct Mark I simulator	21	26 Nov 71
3	Collect data for use in Mark I simulator	24	17 Dec 71
4	Validate Mark I simulator	30	28 Jan 72
5	Conduct sensitivity analyses preliminary to designing Mark II simulator	60	25 Aug 72
6	Design Mark II simulator	70	3 Nov 72
7	Construct Mark II simulator	76	15 Dec 72
8	Collect additional data for Mark II simulator	70	3 Nov 72
9	Validate Mark II simulator	88	9 Mar 73

Each task will be divided into four or more specific sub-tasks. The resulting 72 sub-tasks will, for administrative purposes, form the basic work units of the study. These sub-tasks are described in Appendix 2. The lead activity responsible for the completion of a sub-task may further divide it for internal administrative purposes. The sub-tasks described in Appendix 2 are all required to complete the S^4 study.

7. MANPOWER ALLOCATION

Table 1 lists the manpower requirements (expressed in man-weeks of effort) at each activity to complete each of the nine tasks. Activities not listed in Table 1 but included in the manning requirements of the study directive will provide consulting, training, advisory, or data collecting services at irregular intervals.

8. FUNDING ALLOCATION

Contract research will develop methods for estimating relationships between the time required to perform various processes -- transmit requisitions, acquire material, issue material and move it to the end user -- and resources required to execute these processes at various speeds (such as computers, personnel, materials handling equipment and transportation and communications systems). This is listed as sub-task 6.2 in Appendix 2. The estimated funding required for this research is $75,000, to be made available from FY 72 RDT&E,N funds.

A contractor not otherwise associated with the study will advise the CNO Project Officer and his assistants on proposed solutions to technical problems arising during the course of the study. The estimated funding required for this contractual assistance is $15,000, to be made available from FY 72 and FY 73 RDT&E,N funds.

9. OTHER RESOURCES

In addition to the resources required in paragraphs 7 and 8 above, the following resources will be required to complete this study:

a. Computer Rental

FY 72	300 hrs @ $225/hr	$ 67,500
FY 73	150 hrs @ $225/hr	33,750
TOTAL		$101,250

b. Travel

FY 72	$ 5,000
FY 73	2,500
TOTAL	$ 7,500
GRAND TOTAL	$108,750

10. REPORTS

a. Interim reports will be given to the Study Advisory Committee on 1 January 1972 and 15 August 1972. The final report will be submitted on 1 March 1973.

b. Except as noted in Appendix 2, each sub-task will, upon completion, be the subject of a technical memorandum, copies of which will be made available to the members of the study team, OP-964, and the Advisory Committee.

c. Monthly progress reports will be made in accordance with CNO Project Officer's Handbook OPNAV 96-1A.

SCHEMATIC OF SUPPLY SYSTEM SIMULATOR, MARK I

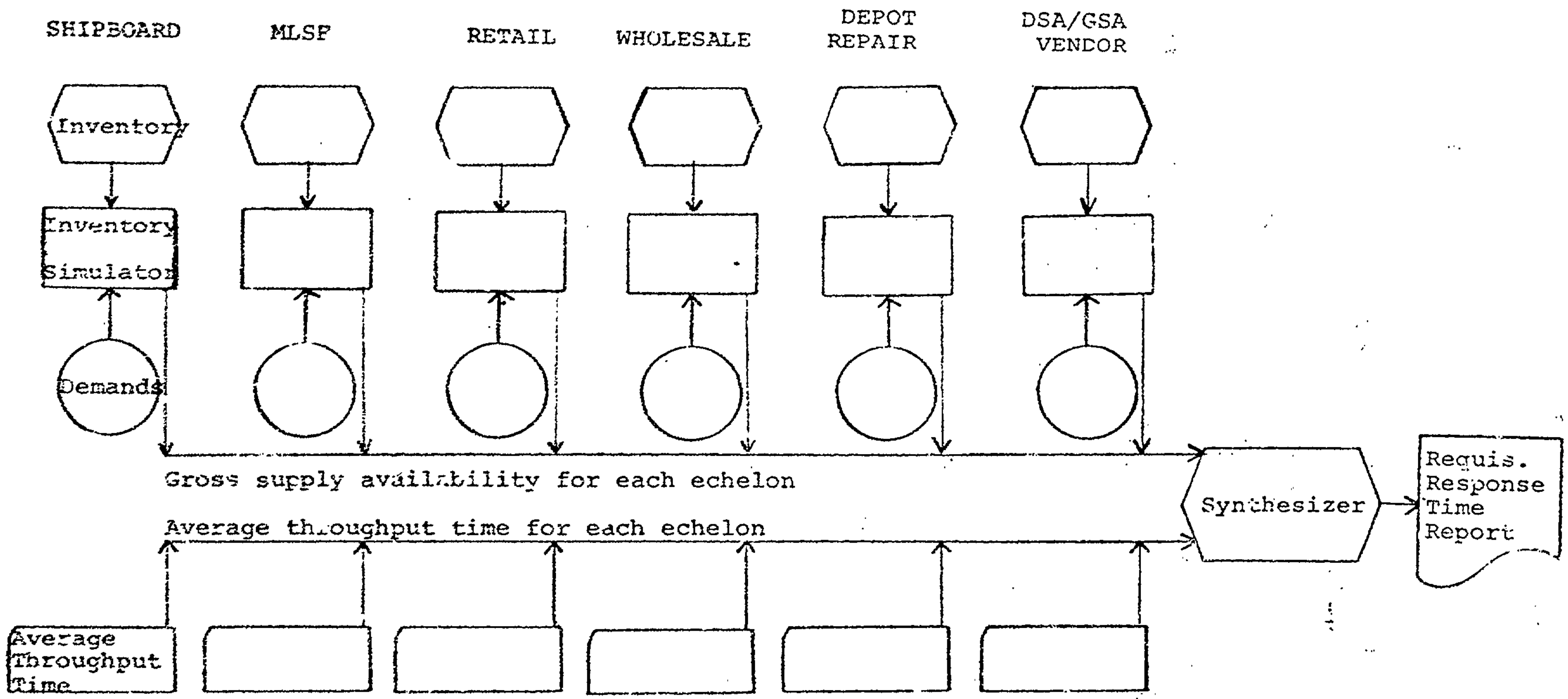

CHART 1

SCHEMATIC OF SUPPLY SYSTEM SIMULATOR, MARK II

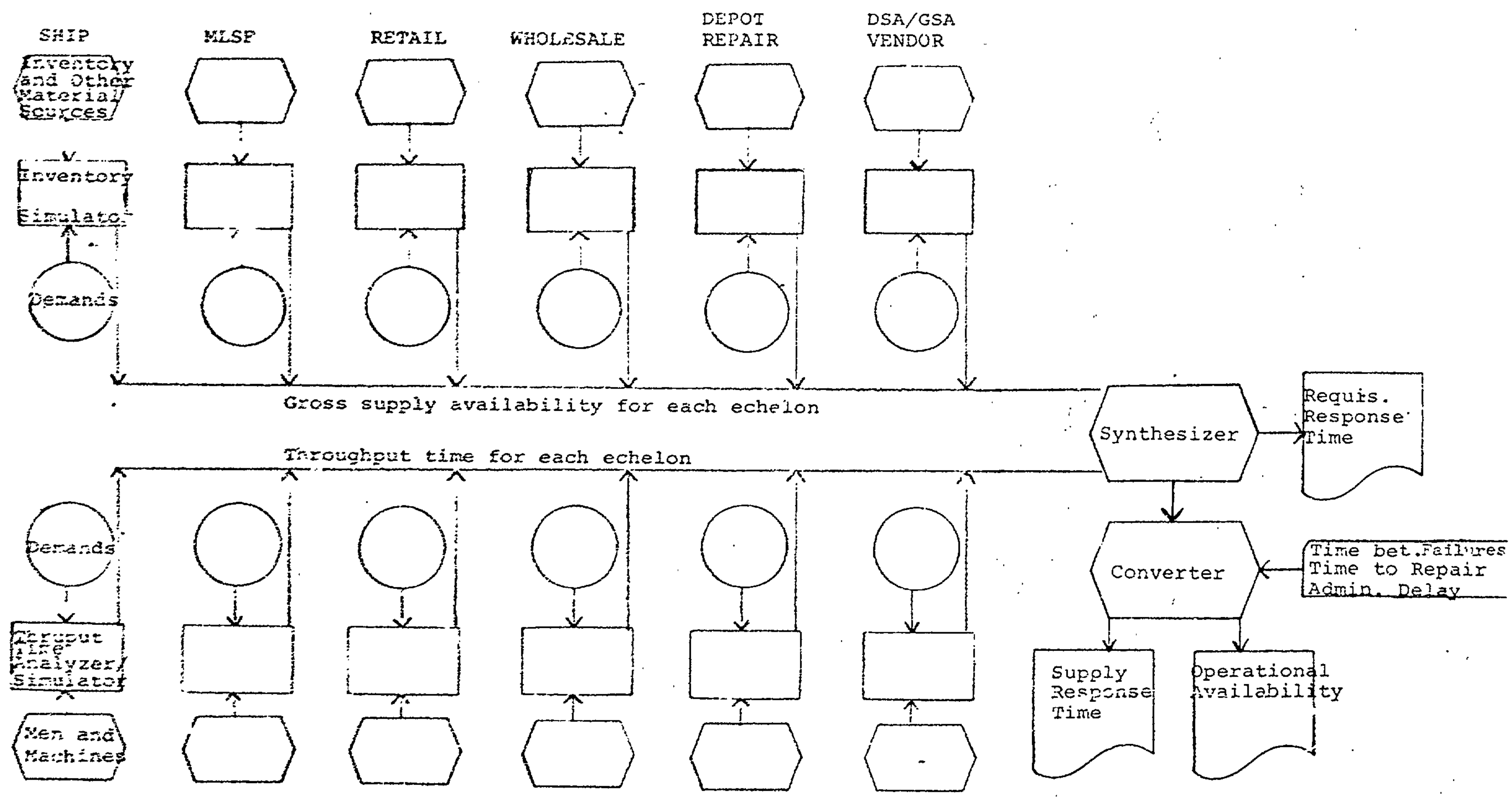

CHART 2

MANPOWER REQUIREMENTS

TASK	PRODUCTIVE MAN WEEKS**			
	OPNAV	NAVSUPSYSCOMHQ	FMSO	MSO
1	3	6	13	8
2	1	2	29	28
3	2	1	29	1
4	-	1	17	15
5	4	6	34	45
6	-	13	39	42
7	1	1	77	20
8	-	-	140	52
9	1	2	56	13
TOTAL	12	32	434	224
		GRAND TOTAL		702

**Excludes leave and holidays.

TABLE 1

APPENDIX 1

DETAILED METHODOLOGY

a. The objectives on the study will be achieved in the main by the development and exercise of two Supply System Simulators -- a combination of several analyzers and simulators designed to explore the relationships among material, O&MN and SCN funds available for various logistics purposes and the response time that can be achieved by these funds.

b. Both simulators employ the same basic equation for requisition response time for an n echelon system which is:

$$R = a_1 t_1 + (1-a_1)\, a_2 t_2 + (1-a_1)(1-a_2)\, a_3 t_3 + \ldots + \prod_{i=1}^{n-1} (1-a_i)\, a_n t_n$$

where: a_i = probability that the ith echelon activity will be able to satisfy an end use requisition not satisfied by a lower echelon (gross availability).

t_i = time from mechanic's need for a unit of material until his receipt of material from an activity in the ith echelon (throughput time).

c. The first (Mark I) version of the Supply System Simulator investigates the supply effectiveness (a_i) of each echelon as a function of funds available for investment in stock at that echelon; it assumes t_i to be given. Values of a_i are estimated by looking at a representative number of items demanded of representative activities at each echelon. Specifically for S^4, the Sixth Fleet and its supporting echelons will be investigated.

d. Most, if not all, of the Sixth Fleet combatant ships will be selected for analysis. For each ship the demand for parts created by mechanics aboard ship will be compared with stocks aboard the ship (initially assumed to be Consolidated Shipboard Allowance List (COSAL) stocks) by means of an analyzer or simulator to calculate the fraction of demands satisfied from shipboard stock. The Fleet Material Support Office now has available in its records and computer programs the COSAL quantities, shipboard demands, and simulators needed to compute a_1 for the majority of the ships in the Sixth Fleet. Because demand and COSAL information are available by Federal Stock Number (FSN), it is possible to get many sets of a_1 for each ship. For the S^4 study, separate values of a_1 (and of a_i in general) will be computed for each significant alpha-numeric cognizance symbol of material.

e. Once values of a_1 have been computed for shipboard stocks, partitioned as above, these can be translated into statements of support of a particular weapon system. This is done by partitioning the weapon system in the same way. A hypothetical weapon system might be described as follows:

Cog Symbol of Failed Part	Consumption per Unit Time	a_1 for Cog Symbol	Consumption Satisfied from COSAL
1N	15	.75	11.25
2N	8	.60	4.80
1H	12	.75	9.00
9N	40	.85	34.00
9Z	20	.80	16.00
Part Number	5	.00	0.00
TOTALS	100		75.05

Hence, 75 percent of the requirements of this weapon system can be satisfied from COSAL stock.

f. Similarly, values of a_i can be computed for the Mobile Logistics Support Force (MLSF) echelon, given demands placed against the fleet issue ship, repair ship, or submarine tender and the loads carried aboard these ships. Note that the demands placed on MLSF ships will not be the sum of the demands used to compute a_i above, but will represent the demands actually placed on Sixth Fleet MLSF ships in the recent past.

g. In a similar fashion, the gross supply availability characteristic of the retail echelon (typified by the Naval Supply Center, Norfolk) for both Navy managed material and DSA/GSA managed material can be computed or observed. (At least for the initial set of experiments performed on both the Mark I and the Mark II simulators, the performance of DSA and GSA -- including the availability of DSA owned and managed material at NSC Norfolk -- will be considered an exogenous variable, uncontrolled by the Navy, and therefore, to be observed rather than computed). Finally, the supply availability of the wholesale supply system (all activities exclusive of NSC Norfolk that report stock status) will be computed. The availability of stock from the last echelon -- the vendor or manufacturer -- is assumed to be unity.

h. There will be two digressions from the general flow of requisitions described above. The first is the local purchase of material, when authorized, by NSC Norfolk; the second is the use of repair in lieu of some manufacture at the wholesale echelon. However, the following sources of material will be ignored in the Mark I version of the simulator: shipboard and tender repair, fabrication at any but the manufacturing echelon, substitution of a similar item or next higher assembly, or cannibalization.

i. Values of a_i as described above can be calculated not only for authorized stock but also for actual stock levels as reported through the ACCESS system. When this is done, calculations can be validated by comparing the results with observations of availability from the real world.

j. For the Mark I simulator, throughput times to receive material (t_i) will be observed, not computed. For each echelon t_i will be composed of (1) sum of times to process not-carried (NC) or not-in-stock (NIS) requisition through each of the lower numbered echelons, plus (2) time to transmit requisition from each of the lower numbered echelons to the next echelon, plus (3) processing time at the ith echelon activity, plus (4) transportation time to requesting mechanic. Throughout these four phases, the requisition and material will be assumed to be given the expedited treatment actually accorded an IPG (Issue Priority Group) 1 or IPG 2 requisition. The following sources of information will be used to obtain processing times: MILSTEP Reports, Formats I and II; master stock records at ICPs and stock points; local activity records; and ad hoc investigations. Separate values of elapsed times will be estimated for each alpha-numeric cognizance symbol, except where there are insufficient observations in a given cognizance symbol to yield a statistically valid result.

k. Note that the throughput times described above for end-use requisitions are quite different from the routine resupply times (i.e., - leadtime or order and shipping time) that must be observed in order to compute a_i for each echelon. Values of t_i are applicable only to end-use requisitions flowing through the supply echelons and end-use material being delivered directly to the ultimate user, possibly through several freight handlers. It is assumed that such requisitions and material are given processing treatment equivalent to IPG I and II requisitions.

l. Once values of a_i and t_i have been computed as described above, they can be combined to form an estimate of requisition time (R) for each kind of material for typical ships in the

Sixth Fleet and for the Sixth Fleet as a whole. Then the effect on R of changing a_i and t_i and the cost associated with a given change in a_i can be observed.

m. Estimates of R need not be single valued. The can, for example, be subdivided by weapon system, as described in paragraph e above. In addition, a distribution of response times can be estimated either (1) by displaying separately the (weighted) mean values of response time characteristic of each echelon or (2) by combining (weighted) histograms of response times from each echelon.

n. The Mark II version of the Supply System Simulator will refine and extend the Mark I version by linking requisition response time (R) to supply response time (S) and this to the operational availability (A_o) of selected weapons systems, by relating processing times (t_i) to processing costs, by including alternate methods for supplying material, by allowing for stock rationing as well as expedited processing, and by modelling the transient responses to changes in the system. Refinements will be accomplished in the priority listed above.

o. Because repair actions may involve more than one replacement part, the average repair job delay due to lack of parts is greater than the average time required to satisfy an individual requisition. A functional relationship will be developed relating requisition response time (R) to the average time a repair is delayed for lack of parts -- the supply response time (S). Note that S may vary by weapons system because (1) the parts replaced bear different cog symbols and (2) some weapons systems require more parts per repair than others.

p. Once S is known by weapon system, it can be combined with other characteristics of the system to produce an estimate of the operational availability of the weapon system through the following expression.

$$A_o = \frac{F}{F + M + D + S}$$

where A_o = operational availability

F = time between failures

M = time to repair

S = parts delay time

D = administrative delay time

q. The most difficult and time consuming task in the design of the Mark II simulator involves the modelling of response time as a function of processing resources and their costs -- personnel, computers materials handling equipment and transportation and communication systems. Only if reasonably realistic modelling can be accomplished in this area will it be possible to assess the consequences of trading-off computers for transportation systems or office personnel for materials handling equipment. In fact, only if the costs of faster processing can be estimated can trade-offs among inventories at different echelons be accurately gauged.

r. Two general approaches to this problem have been suggested although neither has been tried on a large scale. The first is to produce a flow simulation which will accurately and in detail describe the flow of requisitions and material between echelons and within an activity in an echelon. To simplify the design and running of such simulators, one might be nested within another. Thus, one very coarse simulator might portray the flow of a requisition to the ith echelon and the return of material to a customer while several nested simulators would predict requisition processing times within each echelon and material processing times within the ith echelon.

s. Another approach is correlation analysis, where, by examination of available input and output data, it is possible to estimate the marginal decrease in processing time from adding one unit of production.

t. In the event, it is probable that both approaches will be used -- a coarse flow simulator to tie together individual small processes, the costs and throughput times for which have been estimated by correlation analysis. It is clear that conceptual work needs to be done in this area before the actual design of the Mark II simulator is started.

u. The advanced version of the Supply System Simulator should include three additional subtleties ignored in the basic version. The first of these is the adjustment in performance and cost resulting from unusual sources of supply -- cannibalization, substitution, salvage, use of next higher assembly, tender repair, and local fabrication. It may be necessary to introduce these as modifications to the basic process as were depot repair and local purchase in the Mark I version; on the other hand, it may be sufficient to introduce appropriate adjustments to the answers from the main simulator resulting from side analyses.

v. The effects of stock rationing should also be considered. This is the process of setting aside predetermined amounts of stock solely for the satisfaction of high priority requisitions. This is an extension of the expedited processing high priority requisitions now receive.

w. Finally, some estimate should be made of the speed with which input changes affect the output of the system. Because large numbers of requisitions flow through the system quite rapidly, changes in processing resources should lead quickly to changes in output. On the other hand, changes in inventory policies and levels may not be felt at the consuming end of the supply system for some time -- possibly one to three years. The modeling of these one to three year transient responses in the main simulator will probably be quite difficult. Instead, side simulations or analyses should be sufficient to give a rough estimate of transient effects.

x. In the S^4 study neither simulator will consider one end-use demand more important than another, despite the fact that several basic proposals have been made for handling relative item importance.

(1) The first of these is that each weapon system be assigned a relative military essentiality, which would be used to weight demand. In practice no essentiality classification scheme has been developed for General Purpose Force equipment that does not involve considerable detailed engineering analysis of the equipment. Such analysis is beyond the scope of this study. However, provision will be made for segregating outputs according to weapon system essentiality, when known.

(2) A second approach is to characterize failures according to the effect on ship's mission. Such characterization is now being included in the 3-M Data Collection System, but has not been available for a long enough time to provide a sound data base.

(3) A third proposal is to look only at parts involved in casualties, on the theory that these are the only parts vitally affecting the ship's mission. Unfortunately, the CASREPT is an exception report and may not include those parts needed but locally available. Furthermore casualties account for less than 1% of all end-use shipboard demands. Therefore, there surely are enough processing resources in the Navy to satisfy CASREPT demands rapidly, if the processing resources have no other job. Similarly there is always enough material to satisfy CASREPT demands, if there are no prior demands on the material and if all CASREPT demands can be

anticipated. Thus, to limit the study to CASREPT demands is to ignore the multitude of routine requirements which (a) prevent casualties and (b) delay the satisfaction of CASREPT demands.

APPENDIX 2

DESCRIPTION OF SUB-TASKS

Sub-Task Lead Acty.	Description	Start Date / End Date
1.2 NAVSUP	Determine current actual requisitioning and delivery channels by which Sixth Fleet Ships obtain material.	6 July 1971 / 16 July 1971
1.4 FMSO	Review and correct mathematics, logic, and bookkeeping in existing computer products to be used in Mark I Simulator.	6 July 1971 / 23 July 1971
1.6 FMSO	Identify and write additional mathematical and logic statements needed.	19 July 1971 / 6 August 1971
1.8 FMSO	Define data elements required.	2 August 1971 / 6 December 1971
1.10 FMSO	Design Program Modules and Logic.	19 July 1971 / 20 August 1971
2.2 FMSO	Select computer and computer site for Mark I simulator.	2 August 1971 / 10 September 1971
2.4 FMSO	Prepare detailed file specification and layout.	16 August 1971 / 1 October 1971
2.6 FMSO	Prepare detailed computer logic analysis.	16 August 1971 / 1 October 1971
2.8 FMSO	Program computer for Mark I simulator.	4 October 1971 / 12 November 1971
2.10 FMSO	Debug computer program.	8 November 1971 / 26 November 1971

3.2 OP-412	Select Ships and Activities to be Simulated.	19 July 1971 23 July 1971
3.4 FMSO	Acquire demand and inventory data.	26 July 1971 24 September 1971
3.6 FMSO	Acquire elapsed time data.	26 July 1971 6 December 1971
3.8 FMSO	Write and program necessary conversion and aggregation routines.	11 October 1971 29 October 1971
3.10	Combined with Sub-Task 4.4.	
3.12 FMSO	Convert elapsed time data from manual or existing machine format to form required for Mark I simulator.	1 November 1971 17 December 1971
4.2 FMSO	Acquire actual performance data on supply availability and requisition response time.	6 July 1971 3 December 1971
4.4 FMSO	Simulate response of current inventories at each echelon and compare with availability figures.	8 November 1971 3 December 1971
4.6 FMSO	Modify inventory simulators as necessary and repeat Sub-Task 4.4.	6 December 1971 30 December 1971
4.8 FMSO	Run complete simulator and compare with requisition response time performance.	3 January 1972 14 January 1972
4.10 FMSO	Modify complete simulator as necessary and repeat Sub-Task 4.8.	17 January 1972 28 January 1972

4.12 NAVSUP	Evaluate and revise if necessary the schedule for design and construction of Mark II simulator based on experience with Mark I simulator.	24 December 1971 14 January 1972
5.1 OPNAV	Select weapons systems to be analyzed for estimation of supply response time (S) and operational availability (A_o).	1 November 1971 31 December 1971
5.2 MSO	For representative values of time between failure, administrative delays and time to repair compute changes in operational availability (A_o) for unit change in supply response time (S). Isolate types of equipments and parts not sensitive to changes in S.	6 July 1971 10 March 1972
5.4 FMSO	Given currently observed values of supply availability (a_i), estimate effect on requisition response time (R) of changes in throughput times (t_i).	8 November 1971 14 January 1972
5.6 FMSO	Assuming significantly different values of a_i (especially at first and second echelons) rerun studies in Sub-Task 5.4 to estimate both changes in R and changes in inventory levels resulting from changed a_i.	13 December 1971 14 January 1972
5.8	Combined with Sub-Task 6.6.	
5.9 FMSO	Identify major assumptions in design of Mark I simulator and estimate impact of assumptions of simulator outputs.	28 January 1972 7 April 1972
5.10 FMSO	Identify major assumptions in design of Mark II simulator and estimate impact of assumptions on simulator outputs.	5 May 1972 16 June 1972

5.11 FMSO	Test major assumptions in design of synthesizer.	5 May 1972 30 June 1972
5.12 FMSO	Conduct experiments using the synthesizer and MarkI simulators.	25 February 1972 30 June 1972
6.2 RMC	Conduct research on techniques for relating processing times to required resources and costs thereof.	4 October 1971 28 April 1972
6.4 MSO	Conduct research on relation between requisition response time (R) and supply response time (S).	8 November 1971 10 March 1972
6.6 FMSO	Conduct research on effect and cost of utilizing unusual supply resources, such as cannibalization, fabrication, substitution, issue from tender and shipyards, and use of pool stocks.	6 December 1971 7 April 1972
6.8 FMSO	Conduct research on techniques for and effects of stock rationing at AFS and ICP levels.	6 July 1971 7 April 1972
6.10 NAVSUP	Select basic approach to be taken in Mark II inventory simulators.	27 December 1971 28 April 1972
6.11 NAVSUP	Select basic approach for processing simulators.	28 April 1972 23 June 1972
6.12 FMSO	Complete mathematical and logic design of Mark II inventory simulators.	28 April 1972 5 May 1972
6.13 FMSO	Complete mathematical and logic design for processing simulators.	23 June 1972 14 July 1972

6.14 FMSO	Define data elements required for Mark II inventory simulators.	28 April 1972 12 May 1972
6.15 FMSO	Define data elements needed for processing simulators.	30 June 1972 21 July 1972
6.16	Combined with Sub-Task 6.12.	
6.17 FMSO	Complete design of synthesizer for Mark II simulators.	30 June 1972 11 August 1972
7.1 FMSO	Select computer and location for synthesizer.	25 August 1972 8 September 1972
7.2 FMSO	Select computer and computer location for inventory simulators.	1 May 1972 2 June 1972
7.3 FMSO	Select computer and computer location or processing simulators.	14 July 1972 28 July 1972
7.4 FMSO	Prepare detailed file specifications and layout for inventory simulators.	12 May 1972 26 May 1972
7.5 FMSO	Prepare detailed file specifications and layout for processing simulators.	14 July 1972 4 August 1972
7.6 FMSO	Prepare detailed program analysis for inventory simulator.	5 May 1972 2 June 1972
7.7 FMSO	Prepare detailed program analyses for processing simulators.	30 June 1972 11 August 1972

7.8 FMSO	Program computer for Mark II inventory simulators.	12 May 1972 28 July 1972
7.9 FMSO	Program computer for processing simulators.	11 August 1972 6 October 1972
7.10 FMSO	Debug computer programs for inventory simulators.	28 July 1972 25 August 1972
7.11 FMSO	Debug computer programs for processing simulators.	6 October 1972 3 November 1972
7.12 MSO	Define data elements for design, program, and debug converter for converting requisition response time into supply response time and operational availability. Prepare detailed file specifications and layout.	10 March 1972 25 August 1972
7.14 FMSO	Write and debug synthesizer programs.	3 November 1972 15 December 1972
8.2 MSO	Acquire data on time between failures and time to repair.	10 April 1972 28 July 1972
8.3 MSO	Develop profile of selected weapon systems in terms of frequency of parts usage by cog symbol of material.	10 April 1972 28 July 1973
8.4 FMSO	Acquire processing time and associated resource data.	31 March 1972 22 September 1972
8.6 FMSO	Acquire data on frequency with which material is supplied from unusual sources and elapsed time to supply material.	31 March 1972 14 July 1972

8.8 FMSO	Acquire data needed to model rationing process.	31 March 1972 21 July 1972
8.10 FMSO	Write and program various conversion routines needed as inputs to inventory simulators.	16 June 1972 28 July 1972
8.11 FMSO	Program necessary conversion routines for processing time data.	25 August 1972 29 September 1972
8.12 FMSO	Convert inventory data from manual or current machine format to form required for Mark II simulator.	28 July 1972 25 August 1972
8.13 FMSO	Convert processing time and resource data to proper format.	30 September 1972 3 November 1972
9.2 FMSO	Acquire performance and cost data on communication, requisition processing, material processing, and transportation functions as now performed.	19 May 1972 8 December 1972
9.3 MSO	Acquire data on actual supply response time for selected weapons systems in Sixth Fleet from 3-M data.	15 January 1972 25 August 1972
9.4 FMSO	Simulate communication, requisition processing, material processing, and transportation and compare with observed performance.	26 December 1972 5 January 1973
9.5 MSO	Run converter and compare values of supply response time (S) with those observed through 3-M data.	15 January 1972 9 February 1973
9.6 FMSO	Modify processing simulators as necessary and repeat Sub-Task 9.4.	8 January 1973 2 February 1973

9.7 FMSO	Run inventory simulators and compare with observed availability.	25 August 1972 20 October 1972
9.8 FMSO	Run synthesizer and compare with observed performance.	5 February 1973 19 February 1973
9.9 FMSO	Modify inventory simulators as necessary and rerun.	20 October 1972 5 February 1973
9.10 FMSO	Modify synthesizer as necessary and repeat Sub-Task 9.8.	19 February 1973 9 March 1973
9.12 FMSO	Prepare Executive Summary and User's Handbook.	22 January 1973 9 March 1973

APPENDIX C

ANALYZER, SIMULATOR

AND

INVENTORY RULE

DESCRIPTIONS

A. AFLOAT INVENTORY SIMULATOR

B. CONUS INVENTORY SIMULATOR

C. SYNTHESIZER

D. PROCESS ANALYZER

A. AFLOAT INVENTORY SIMULATOR

1. Rules for Determining Range and Depth of Coordinated Shipboard Allowance List (COSAL) Items.

The COSAL is composed of five groups of material*:

°Demand based items - those for which expected quarterly shipboard demand is at least one unit. Quarterly demand is the product of the world-wide average usage, as reported by the 3M MDCS, and the number of installations aboard the ship for which the COSAL is designed.

°Insurance items - those items not qualifying as demand based items but for which expected annual shipboard demand is at least 0.15 units.

°Override items - those not meeting the above criteria but nevertheless required for preventive maintenance or needed to correct a failure that would significantly impair the ship's mission.

°Allowance equipage list (AEL) items, covering primarily high usage, non-technical consumables, such as paper napkins, administrative supplies, etc.

°Operating space items (OSI), such as hand tools, carried in operating spaces and intended for daily use. Because OSI items contribute virtually nothing to the gross supply availability of Supply Department stocks, they are often excluded from statements about COSAL range and value.

Range of COSAL stocks (i.e., number of different items carried) is determined by the rules described above. The depth for demand based items is that amount which will just insure a 90% probability of covering all demands that could arise in 90 days of operation. Where appropriate, the demand rate is adjusted to account for combat consumption. The depth of stock for all insurance items is one minimum replacement unit or, if none is specified, one unit.

2. Rules for Selecting and Determining Depth of Selective Item Management (SIM) Items**.

*Taken from OPNAV Instruction 4441.12
**Taken from NAVSUP Manual, paragraph 6230

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Any item for which two or more demands have occurred aboard ship in six consecutive months is classified as a SIM item for that ship. Demand for SIM items is recomputed at least quarterly based on demands observed in the past 6, 9, or 12 months. Based on recomputed demand, a high limit of $D(E + L + 1/2)$ and a low limit of $D(E + L - 1/2)$ is calculated, where:

D = monthly demand in units

E = endurance period in months

L = order and shipping time in months

The endurance period is generally three months (90 days) but may be reduced by the Type Commander. Order and shipping time varies between 0 and 3 months. For Sixth Fleet ships, it is 1 month for Fleet Issue Load List items, 2 months for other items.

When on-hand and on-order stocks of a SIM item reach the low limit, enough stock is ordered to bring the total up to the high limit.

Type Commanders may modify shipboard range and depth rules in the light of operational or financial circumstances. For example, ships on extended isolated tours may be authorized a 3 month order and shipping time; high and low limits on non-SIM items may be reduced to 1 minimum replacement unit and 0 units, respectively.

SIM selection and depth rules are applied by SOAP (Ships Overhaul Assistance Program) teams during a ship's overhaul and by shipboard personnel at all other times. The combination of COSAL and SIM items constitutes the initial stock list (ISL).

3. Fleet Issue Load List Construction

a. The general procedure for determining the <u>range</u> of items to be carried on the Atlantic Fleet FILL is this:

°If the item's demand (expressed in requisitions) from all Atlantic Fleet ships is greater than or equal to F_1, stock the item in a depth to be described below.

°If the item's demand lies between F_1 and F_2 (where $F_2 < F_1$) <u>and</u> if the item's price is less than or equal to C_1 dollars, stock 1 unit on the FILL.

°Otherwise stock nothing.

In practice F_1 has been set equal to F_2, so that an item makes or fails to make the FILL based solely on requisitions demanded, currently set at 15 in two years.

b. The depth of the FILL for a given item is the greater of 1 unit or the FIRL (Fleet Issue Requirements List) divided by the number of FILLs authorized for the Fleet. (For the Atlantic Fleet 3 loads are currently authorized.) The FIRL quantity, in turn, is calculated to satisfy 90 percent of the units demanded during a mobilization support period. In particular, the FIRL quantity is:

$$\bar{D}\,K\,E + t\,\sigma\sqrt{KE}$$

where: $\bar{D}$ is average quarterly demand

K is combat tempo factor

E is the support period in quarters (currently set at 1)

t is the number of standard deviations in the Gaussian distribution such that:

$$\text{Prob}(\text{Demand in } E > \bar{D}\,K\,E + t\,\sigma\sqrt{KE}) = \frac{\lambda\,C}{\bar{D}KE}$$

C is the item's unit price

σ is the item's quarterly standard deviation of demand

λ is a control variable used to reach overall desired effectiveness

C. In addition to the FILL quantity, which is computed by FMSO and prescribed by the Fleet Commander, the AFS Supply Officer can add depth based on local conditions. The increased depth is called POS (peacetime operating stock). For an item to qualify initially for POS stock, it must have a minimum number of demands in 6 months. To be retained as a POS item it must pass a lower minimum.

The depth of POS stock (which is added to the FILL quantity) is:

$$A\sqrt{\frac{\bar{D}}{C}} + \bar{D}L + B\bar{D}$$

where: A is a control variable to adjust the amount of operating stock

L is the order and shipping time

B is the number of quarters of stock in the safety level.

Both $A\sqrt{\frac{\bar{D}}{\bar{C}}}$ and $B\bar{D}$ are constrained within predetermined months of supply. Replenishment occurs when total stock drops to $\bar{D}L + B\bar{D}$ + FILL quantity*.

4. Demand Generation

The method of generating shipboard demand depends on whether demand has been observed and recorded in the recent past. If demand for an item has been observed in the 18-month 3M data collection period, the generating technique described immediately below is used. If demand has not been observed, the generating procedure described in paragraph 4b applies. AFS demands are limited to those appearing on a demand history tape maintained by FMSO and are, by definition, observed.

a. Items with observed demand - Item demand is generated in the following steps:

(1) Compute the average days between requisitions

$$\bar{T} = T/R$$

where T = total days demand was recorded

R = total requisition recorded for item

(2) Compute average requisition size:

$$\bar{S} = D/R$$

where D = total unit demand recorded for item

*For further details, see Uniform AFS Resupply Decision Rules User's Manual; R. J. Gabriel and E. L. Peters; Fleet Material Support Office, 2 September 1971

(3) Generate the actual days to the next requisition:

$$t = [-\bar{T} \log X + 0.5]^{+}$$

where X = uniformly distributed random number between 0 and 1

$[y]^{+}$ = largest integer in y

(4) Generate an actual requisition size:

$$s = \left[\frac{\log X}{\log \left(\frac{\bar{s}}{\bar{s} + 1} \right)} + 0.5 \right]^{+}$$

b. Items without observed demand - The generation of demand for an item with no observed data requires an assumption that the period of observation is a "typical" period. This implies that the items which have observed data will continue to experience similar demand patterns in any other similar time period. The following procedure is then applied to the development of these parameters:

°All items which experienced demand during the period of observation are stratified and counted by cognizance symbol and ship

°All items which could have experienced demand during this period are stratified and counted in the same manner.

°A probability is developed based on the counts; i.e., the probability that an item with the same cog symbol on the same ship will experience demand during a year.

°These probabilities (by cog and by ship) are then used to compute Prob $(D_n = X) = \binom{n}{X} p^X q^{n-X}$, the probability of X demands in n years, for values of X from 0 to n. (For purposes of the current simulation, n will equal 5).

°The value of X implies the expected number of demands to be received during the simulation period. This can then be used to select a mean time between requisitions. For an observation time period of 1 year and a simulation time period of 5 years the mean time between demand in days is 1800/X, unless X is 0, in which case no demand is generated for the item.

5. Weighting Shipboard Outputs

Because the shipboard portion of the Afloat Simulator analyzes a sample of the ships in the Sixth Fleet, it is necessary to weight the several outputs for each sample ship type according to the prevalence of that ship type in the actual fleet. The value of the ship data elements for number of items carried, number of requisitions received per year, value of annual demand, value of inventory, value of intransit inventory and number of resupply orders is computed by use of the following formula:

$$v_j = \frac{\sum_{i=1}^{n} V_{ij} W_i}{\sum_{i=1}^{n} W_i}$$

where:

v_j = the value of the element of interest (e.g., items carried, requisitions, etc.) for the j^{th} cog

V_{ij} = the observed value of the element of interest for the i^{th} ship and the j^{th} cog

W_i = the appropriate weight assigned to the i^{th} ship

n = the number of ships

The availability and throughput time at the shipboard echelon are also a weighted average and computed in a manner similar to the formula cited above. However, since a ratio is being computed it is necessary to weight both the numerator and denominator. The following formulae display these computations:

$$a_j = \frac{\Sigma\, S_{ij}\, W_i}{\Sigma\, P_{ij}\, W_i} \text{ and } t_j = \frac{\dfrac{\Sigma S_{ij}\, W_i\, T_i}{\Sigma\, P_{ij}\, W_i}}{a_j}$$

where:

a_j = weighted shipboard availability of material for the j^{th} cog

t_j = weighted shipboard throughput time for j^{th} cog

S_{ij} = the number of requisitions satisfied by the inventory of the i^{th} ship for the j^{th} cog

P_{ij} = the number of requisitions placed on the inventory of the i^{th} ship for the j^{th} cog

W_i = the appropriate weight assigned to the i^{th} ship

T_i = average throughput time on i^{th} ship

B. AFLOAT INVENTORY SIMULATOR

1. Replenishment Rules Used by Inventory Control Points

(a) Demand forecasting - Quarterly demand observations are single exponentially smoothed according to the following expression:

$$\bar{D}_1 = \alpha D_0 + (1 - \alpha) \bar{D}_0$$

where $\bar{D}_1$ is the forecast for the coming period

$\bar{D}_0$ is the forecast for the current period

D_0 is the demand observed during the current period

α is a smoothing constant, $0 < \alpha = 1$

The above smoothing is applied to demand, to returns of non-RFI carcasses, to procurement leadtime, and to repair turn-around time.

In actual operation, D_0 is tested before it is accepted into the above formula to make sure that the value is not extremely unlikely. In addition, there are tests for a step or trend in demand, resulting either from past observations or anticipated changes in program level. None of these tests is included in the simulated version of ICP operations.

Standard deviation of demand is computed as 5/4 of Δ_1 which is:

$$\Delta_1 = \alpha |\bar{D}_0 - D_0| + (1 - \alpha) \Delta_0$$

where Δ_0 and Δ_1 are the current and previous mean absolute deviations.

(b) Order and repair quantities - The order and repair quantities (Q) computed by the ICPs and in the simulation are:

$$Q_1 = \text{Consumable order quantity} = \sqrt{\frac{8A\bar{D}}{ac}}$$

$$Q_2 = \text{Repairable item order quantity} = \sqrt{\frac{8A(\bar{D}-\bar{R})}{ac}}$$

Q_3 = Repairable item repair quantity $= \sqrt{\dfrac{8A\bar{D}}{ac'}}$

where A is the cost of purchasing or inducting for repair

a is the holding cost per annum per dollar of inventory

c is the unit purchase cost

$\bar{R}$ is the quarterly carcass return rate

c' is the unit repair cost

The order and repair quantities computed as above are constrained not to exceed the shelf life, technical life or program life of the item, not to exceed some arbitrary ceiling on purchase quantity, and not to fall short of $25 worth, 3 months worth, or 1 intermediate unit pack. In actual practice but not in the simulation, order quantities are adjusted to take account of price breaks.

(c) Risks and reorder points - A risk of stock-out and a reorder point are calculated for each order and repair quantity; the reorder point is then compared with available stock to decide whether to buy or repair.

Stock-out risk, consumable item = $\dfrac{acsQ_1}{\lambda E\bar{D} + acsQ_1}$

Stock-out risk for purchasing reapirable =

$$\frac{acsQ_2}{\lambda E(\bar{D}-\bar{R}) + acsQ_2}$$

Stock-out risk for repairing repairable =

$$\frac{ac'sQ_3}{\lambda E\bar{D} + ac'sQ_3}$$

where: s = average requisition size in units

λ = imputed shortage cost, adjusted to meet specified performance goal or to live within budget

E = relative item essentiality

The associated reorder (or repair) point is the smallest quantity of stock for which the probability of greater demand during the leadtime is no more than the stock-out risk given above. The mean leadtime demand is defined to be:

$\overline{DL}$; $(\bar{D} - \bar{R})\ \bar{L} + \bar{R}\ (\bar{L} - \bar{T})$; or

$\overline{RT}$, respectively, where:

$\bar{L}$ = average procurement leadtime

T = average repair-turn-around time

The assumed demand distribution is negative binomial, Poisson or Gaussian, depending on the value of the mean just described.

2. Demand Generation

If one or more demands has been recorded in the ICP files within the past two years, demands are generated as in Section A4a of this Appendix. For items not appearing on the demand records in the last two years a special analysis was made of the Demand History Files at ESO and SPCC, with the results shown in Table C-1. This table, based on an analysis of the 73,000 items at SPCC and almost 29,000 items at ESO showing no replenishable demand in two years, is used in conjunction with a random number generator to determine how many units ($\bar{D}$) of a slow moving item might be demanded in five simulated years. Then the average time between requisitions is:

$$\bar{T} = \frac{1800\ \bar{s}}{\bar{D}}$$

where $\bar{s}$ is the average requisition size, taken from one of the last two columns of Table C-1. These requisition sizes are typical of SPCC items with demand in the most recent two years; it is assumed that ESO items have about the same requisition sizes.

Given $\bar{T}$ and $\bar{s}$, item demands are generated as described in Section A4a of this Appendix.

Note that the 73,000 items without replenishable demand in the past two years constitute 32% of the items that have been stocked by SPCC for at least two years and that additional items may have had non-replenishable demand during that period. A similar analysis of ESO items is not available.

DISTRIBUTION OF DEMANDS

FOR SLOW MOVING ITEMS

Units Demanded	Cumulative Percent		Average Requisition Size	
	ESO	SPCC	Consumable	Repairable
0	36.11%	52.49%	0	0
1	62.38	69.16	1	1
2	73.65	78.13	2	2
3	79.66	82.52	3	3
4	83.97	86.32	4	4
5	87.24	88.75	1.849	1.867
6	89.92	90.97	1.849	1.196
7	91.55	92.24	1.947	1.562
8	93.17	93.64	1.954	1.570
9	94.24	94.43	1.887	1.838
10	95.65	95.67	1.852	1.443
11	96.41	96.28	1.856	1.809
12	97.19	97.13	1.945	1.743
13	97.66	97.54	1.867	1.697
14	98.07	97.95	2.195	1.859
15	98.47	98.36	2.095	1.456
16	98.91	98.82	2.293	1.689
17	99.14	99.06	2.318	1.934
18	99.39	99.32	1.998	1.763
19	99.58	99.49	2.402	2.273
20	100.00	100.00	2.260	2.028

TABLE C-1

C. SYNTHESIZER COMPUTATIONS

1. Call in Inventory File - Echelon 1, cog 1H, base values of case 1 and all data for case under analysis (case k).

2. Compute: inventory $(\overset{\circ}{\overset{*}{\hat{I}}}_{1,1H,k})$, \$ obligations $(\overset{\circ}{\hat{P}}_{1,1H,k})$, items carried $(\overset{\circ}{\hat{K}}_{1,1H,k})$, resupply requisitions $(\hat{Y}_{1,1H,k})$, and gross availability $(\hat{A}_{1,1H,k})$ as linear interpolations of data in Table 1,1H,k. (Barred values are base values from case 1; those with caret are interpolated or computed values; those with asterisk needed only for incremental resource analysis portion of report; and those with a circle needed only for inventory, workload, and performance.)

3. Compute: requisitions issued, $\hat{S}_{1,1H,k} = \hat{A}_{1,1H,k} W_{1,1H}$

requisitions referred, $\hat{N}_{1,1H,k} = (1-\hat{A}_{1,1H,k}) \bar{W}_{1,1H}$

requisitions received, $G_{1,1H,k} = \bar{W}_{1,1H}$ = base case requisitions received

basic requisitions satisfied $= \bar{S}_{1,1H} = \bar{A}_{1,1H} \bar{W}_{1,1H}$

basic inventory $\overset{*}{\bar{I}}_{1,1H} = \bar{I}_{1,1H}$

cumulative availability $\hat{V}_{1,1H,k} = \hat{A}_{1,1H,k}$

4. Call in cogs 2H through 9Z, base values of case 1 and all data for case under analysis. Repeat computations in steps 2 and 3.

5. Call in echelon 2 (AFS), 1H cog, cases 1 and k and compute:

$\overset{\circ}{\overset{*}{\hat{I}}}_{2,1H,k}$ as above

$\overset{\circ}{\hat{P}}_{2,1H,k}$ as above

$\overset{\circ}{\hat{K}}_{2,1H,k}$ as above

$\hat{Y}_{2,1H,k}$ as above

$\hat{A}_{1,1H,k}$ as above

requisitions received $\hat{G}_{2,1H,k} = \bar{W}_{2,1H}\left\{\dfrac{N_{1,1H,k} + Y_{1,1H,k}}{\bar{N}_{1,1H} + \bar{Y}_{1,1H}}\right\}$

where $\bar{N}_{1,1H} = (1-\bar{A}_{1,1H})\ \bar{W}_{1,1H}$

requisitions issued $\hat{S}_{2,1H,k} = A_{2,1H,k}\ \hat{G}_{2,1H,k}$

requisitions referred $\hat{N}_{2,1H,k} = (1-A_{2,1H,k})\ G_{2,1H,k}$

basic inventory $\bar{I}^{*}_{2,1H,1} = \bar{I}_{2,1H}$

basic requisitions satisfied $\bar{S}_{2,1H} = \bar{A}_{2,1H}\ \bar{W}_{2,1H}$

cumulative availability $= V_{2,1H,k} = (1-V_{1,1H})\ A_{2,1H,k} + V_{1,1H,k}$

6. Call in cogs 2H through 9Z and repeat step 5.

7. Call in echelon 3, (screening) 1H cog, cases 1 and k, and compute:

   availability $A_{3,1H,k} = A_{3,1H,k}$

   requisitions received $G_{3,1H,k} = \bar{W}_{3,1H}\left\{\dfrac{N_{2,1H,k}}{\bar{N}_{2,1H}}\right\}$

   where $\bar{N}_{2,1H} = (1-\bar{A}_{2,1H})\ \bar{W}_{2,1H}$

   requisitions issued, $\hat{S}_{3,1H,k} = \hat{A}_{3,1H,k}\ G_{3,1H,k}$

   requisitions referred, $N_{3,1H,k} = (1-\hat{A}_{3,1H,k})\ G_{3,1H,k}$

   cumulative availability, $V_{3,1H,k} = (1-\hat{V}_{2,1H,k})\ \hat{A}_{3,1H,k} + V_{2,1H,k}$

   basic requisitions referred $= \bar{N}_{3,1H} = \bar{W}_{3,1H}\ (1-\bar{A}_{3,1H})$

8. Call in cogs 2H through 9Z and repeat step 7.

9. Call in echelon 4, (Norfolk), cog 1H, base values of case 1 and all data for case under analysis.
Compute:

$\overset{o*}{\hat{I}}_{4,1H,k}$ as in echelon 1 above

$\overset{o}{\hat{P}}_{4,1H,k}$ as in echelon 1 above

$\overset{o}{\hat{K}}_{4,1H,k}$ as in echelon 1 above

$\hat{Y}_{4,1H,k}$ as in echelon 1 above

$\hat{A}_{4,1H,k}$ as in echelon 1 above

requisitions received, $\hat{G}_{4,1H,k} = \bar{W}_{4,1H}\left\{\frac{\hat{N}_{2,1H,k} + \hat{Y}_{2,1H,k} - \hat{S}_{3,1H,k}}{\bar{N}_{2,1H} + \bar{Y}_{2,1H} - \bar{S}_{3,1H}}\right\}$

where $\bar{S}_{3,1H} = \bar{A}_{3,1H}\,\bar{W}_{3,1H}$

requisitions issued, $\hat{S}_{4,1H,k} = \hat{A}_{4,1H,k}\,G_{4,1H,k}$

requisitions referred, $\hat{N}_{4,1H,k} = (1-\hat{A}_{4,1H,k})\,\hat{G}_{4,1H,k}$

basic inventory, $\overset{*}{\bar{I}}_{4,1H,} = \bar{I}_{4,1H}$

cumulative availability = $\hat{V}_{4,1H,k} = (1-\hat{V}_{3,1H,k})\,A_{4,1H,k} + \hat{V}_{3,1H,k}$

basic requisitions satisfied = $\bar{S}_{4,1H} = \bar{A}_{4,1H}\,\bar{W}_{4,1H}$

10. Call in cogs 2H through 9Z and repeat step 5.

11. Call in ICP data (echelons 5-9), 1H cog base values of case 1 and 1 data for case under consideration. Compute for echelon 5 (referral):

$\overset{o*}{I}_{5,1H,k}$ as in echelon 1

$\overset{o}{K}_{5,1H,k}$ as in echelon 1

$\overset{o}{P}_{5,1H,k}$ as in echelon 1

$\hat{Y}_{5,1H,k}$ as in echelon 1

$\hat{A}_{5,1H,k}$ as in echelon 1

Requisitions received, $\hat{G}_{5,1H,k} = \overline{W}_{5,1H} \left\{ \frac{\hat{N}_{4,1H,k}}{\overline{N}_{4,1H}} \right\}$

where $\overline{N}_{4,1H} = (1-\overline{A}_{4,1H}) \; \overline{W}_{4,1H}$

requisitions issued, $\hat{S}_{5,1H,k} = \hat{A}_{5,1H,k} \; \hat{G}_{5,1H,k}$

cumulative availability $= \hat{V}_{5,1H,k} = (1-V_{4,1H,k}) \; \hat{A}_{5,1H,k} + \hat{V}_{4,1H,k}$

basic inventory $\overset{*}{\overline{I}}_{5,1H} = \overline{I}_{5,1H}$

basic requisitions issued $= \overline{S}_{5,1H} = \overline{A}_{5,1H} \; W_{5,1H}$

12. Compute for echelon 6 (backorder):

$\dot{A}_{6,1H,k}$ as in echelon 1

requisition issued, $\hat{S}_{6,1H,k} = \hat{A}_{6,1H,k} \; \hat{G}_{5,1H,k}$

cumulative availability $\hat{V}_{6,1H,k} = (1-\hat{V}_{4,1H,k}) \; \hat{A}_{6,1H,k} + \hat{V}_{51H,k}$

basic requisitions issued $= \overline{S}_{6,1H} = \overline{A}_{6,1H} \; \overline{W}_{5,1H}$

13. Compute for echelon 7 (spot buy):

$\dot{P}_{7,1H,k}$ as in echelon 1

$\dot{A}_{7,1H,k}$ as in echelon 1

requisitions issued, $\dot{S}_{7,1H,k} = \hat{A}_{7,1H,k} \; \hat{G}_{51H,k}$

cumulative availability, $\hat{V}_{7,1H,k} = (1-\hat{V}_{6,1H,k}) \; \hat{A}_{7,1H,k} +$
$\dot{V}_{6,1H,k}$

basic requisitions issued, $\overline{S}_{7,1H} = \overline{A}_{7,1H} \; \overline{W}_{5,1H}$

14. Compute for echelon 8 (spot repair):

$\overset{o}{\hat{K}}_{8,1H,k}$ as in echelon 1

$\overset{o}{\hat{P}}_{8,1H,k}$ as in echelon 1

$\overset{o}{\hat{Y}}_{8,1H,k}$ as in echelon 1

$\hat{A}_{8,1H,k}$ as in echelon 1

requisitions issued, $\hat{S}_{8,1H,k} = \hat{A}_{8,1H,k} \; \hat{G}_{5,1H,k}$

cumulative availability, $\hat{V}_{8,1H,k} = (1-\hat{V}_{4,1H,k}) \; \hat{A}_{8,1H,k} + \hat{V}_{7,1H,k}$

basic requisitions issued, $\bar{S}_{8,1H} = \bar{A}_{8,1H} \; \bar{W}_{5,1H}$

15. Repeat computations in steps 12 through 14 for 2H through 9Z cogs.

NOTE: All computations given have been for the case in which user wishes to assume a <u>proportional</u> workload change. If he wishes to assume an <u>absolute</u> change, then whenever a term of the form $x\left\{\frac{A}{B}\right\}$ appears in braces, it should be replaced with a term of the form $+\left\{A-B\right\}$

16. Save all computations for report generation.

Save $\hat{V}_{ijk}$, $\hat{N}_{ijk}$, $\hat{S}_{ijk}$, $\bar{N}_{ijl}$, $\bar{S}_{ijl}$, $\overset{o}{\bar{I}}_{ijk}$, $\overset{*}{\bar{I}}_{ijl}$, $\bar{K}_{ijl}$,

$\hat{K}_{ijk}$, $\bar{Y}_{ijl}$, $\hat{Y}_{ijk}$ for further computation.

17. Begin computation of throughput time.

Compute for each leg (m) that the user has selected the ratio:

$$\frac{\sum_i \sum_j F_{jm} \hat{S}_{ijk}}{\sum_i \sum_j F_{jm} \bar{\bar{S}}_{ikl}} = \frac{\Omega_m}{\bar{\Omega}_m} = Z_m$$

and use this ratio to compute by linear interpolation the mean throughput time ($\hat{M}_m$) and the probability of throughput in x days [$Pr(T_m = x)$] if user wants distribution of throughput time. If extrapolation would be required, stop program and print on terminal the leg number involved and value of ratio.

18. For each echelon-cog combination compute:

$\hat{T}_{ijk} = \sum_m F_{jm} \hat{M}_m$ for only those legs appeari[illegible] in an echelon-cog path.

19. For those legs (5, 7, 8, 9, 13, 14, 68, 69, 85) that provide alternate paths, compute:

$Pr\ (T = X) = Q_1\ Pr\ (T = X \mid \text{leg 1 used}) + Q_2\ Pr\ (T = X$

$\mid \text{leg 2 used})$

where $Q_1 = \dfrac{\hat{\Omega}_1}{\hat{\Omega}_1 + \hat{\Omega}_2}$; $Q_2 = 1 - Q_1$

Then for any two legs (m = 1 and m = 2) which appear in an echelon-cog combination and whose dimensions are in hours compute:

$Pr\ (T = x_1 + x_2) = pr\ (T_1 = x_1)\ Pr\ (T_2 = x_2)$

for all combinations of x_1 and x_2. Then, using data about a third leg (m = 3) with hourly dimensions, compute

$Pr\ (T = x_1 + x_2\ x_3) = [Pr\ (T_1 = x_1)]\ Pr\ (T_3 = x_3)$

Repeat this until all legs with hourly dimensions have been included.

Then compute $Pr\ (T = d \text{ days}) = \sum_{x=24(d-1)}^{x=24d} Pr\ (T = x \text{ hours}$

Next combine in a similar manner the probability values for all other legs of interest with the probabilities just computed.

20. For each echelon cog combination, compute:

$$\hat{V}_{ijk} - \hat{V}_{(i-1)jk} = \Delta \hat{V}_{ijk} \quad \text{for all } i \neq 1$$

$$\hat{V}_{ijk} = \Delta \hat{V}_{ijk} \quad \text{for } i = 1$$

$$E_{ijk} = \underline{ith} \text{ echelon's contribution to } R_{jk} = T_{ijk} \, \Delta \hat{V}_{ijk}$$

$$R_{jk} = \sum_{i} E_{ijk}$$

$$Pr\ (R_{jk} = x) = \sum_{i} \Delta \hat{V}_{ijk} \ Pr\ (T_{ijk} = x)$$

$$Pr\ (R_{jk} \leq y) = \sum_{x=0}^{y} Pr\ (R_{jk} = x)$$

$$\Delta \overset{*}{\hat{I}}_{ijk} = \overset{*}{\hat{I}}_{ijk} - \overset{*}{\bar{I}}_{ijl}$$

To assist in manual computation of R for PN cog items, the above computations should be arranged so as to produce and print:

$$\frac{1}{\sum_{i} \Delta V_{ijk}} \ Pr\ (R_{jk} = X) \quad \text{for each cog symbol}$$

and for the following echelons (1):

Echelon 7 alone (spot buy)
Echelons 5 through 7
Echelons 4 through 7

21. Compute for each echelon and the case under consideration:

$$\beta_{I,i,k} = U_{I,i} \left[\sum_{j} \hat{I}_{ijk} - \sum \bar{I}_{ijl} \right]$$

$$\kappa_{K,i,k} = U_{K,i} \left[\sum_{j} \hat{K}_{ijk} - \sum \bar{K}_{ijl} \right]$$

$$\beta_{S,i,k} = U_{s,i} \left[\sum_j \hat{S}_{ijk} - \sum \overline{S}_{ijl} \right]$$

$$\beta_{N,i,k} = U_{N,i} \left[\sum N_{ijk} - \sum \overline{N}_{ijl} \right]$$

$$\beta_{y,i,k} = U_{y,i} \left[\sum \hat{Y}_{ijk} - \sum \overline{Y}_{ijl} \right]$$

where U = marginal cost of producing a unit of output

D. BASIC PROCESS ANALYZER CALCULATIONS

In a three priority queuing system, applicable to Navy requisition processing, it is conventional to assign the numerals 1, 2, and 3 to the highest, medium, and lowest priorities, respectively.

Assume that the arrivals of the first or highest priority have mean arrival rate of a_1 work units per unit time, that the second or middle priority units have mean rate a_2 work units per unit time, and that the third or lowest priority units have mean a_3 work units per unit time, such that their sum is called a. The service rate covering all priorities is u. Let it further be supposed that the first priority items have the right to be served ahead of the others, but that once a service of a priority 2 or 3 work unit is begun, it cannot be interrupted by preemption.

In light of these assumptions, it has been shown* that the expected number of work units in the queuing system for each priority can be fairly easily found in terms of the input and service parameters. If Q_1, Q_2, and Q_3 are used to denote these averages, then we have:

$$Q_1 = \frac{a_1 \sum_{k=1}^{3} (a_k/u^2)}{1 - a_1/u} + \frac{a_1}{u}$$

$$Q_2 = \frac{a_2 \sum_{k=1}^{3} (a_k/u^2)}{(1 - a_1/u)(1 - a_1/u - a_2/u)} + \frac{a_2}{u}$$

$$Q_3 = \frac{a_3 \sum_{k=1}^{3} (a_k/u^2)}{(1 - a_1/u - a_2/u)(1 - a_1/u - a_2/u - a_3/u)}$$

*Cobham, A. (1954). "Priority Assignment in Waiting Line Problems." J. Opns. Res. Soc. Am., 2, 70-76; "A correction." Ibid, 3, 547.

Morse, P. (1958). Queues, Inventories, and Maintenance. John Wiley and Sons, New York.

The mean system waiting times, say W(1), W(2), and W(3), are then found by applying Little's formula, $Q = aW$, on Equation (1), so that $W(1) = Q_1/a_1$, $W(2) = Q_2/a_2$, and $W(3) = Q_3/a_3$. The total average system wait can then be obtained by the weighted average of W(1), W(2), and W(3), namely,

$$W = (a_1/a)\, W(1) + (a_2/a)\, W(2) + (a_3/a)\, W(3).$$

The variances of the system delays for the three priorities are:

$$V(1) = W_2(1) - [W(1) - 1/u]^2 + 1/u^2,$$

$$V(2) = W_2(2) - [W(2) - 1/u]^2 + 1/u^2,$$

and

$$V(3) = W_2(3) - [W(3) - 1/u]^2 + 1/u^2.$$

where: $W_2(k)$ is the second moment of the waiting time for a priority k requisition.

The well-known inequality due to Chebyshev, namely,

$$\Pr\{|X - E[X]| \geq k\sigma\} \leq 1/k^2, \qquad (2)$$

is employed to get the probability distribution governing the waiting times for each of the priorities and then the system distribution is achieved by mixing according to the proper proportions. The use of this inequality will give conservative bounds instead of exact expressions, but these bounds are sufficiently tight for modeling purposes and any final answer would be reasonably robust with respect to the approximation, especially in view of the fact that many such queuing systems will eventually be combined and any errors will tend to neutralize each other in the end.

Specifically, it is assumed that the right-hand inequality in (2) is binding and thus that

$$\Pr\{|X - E[X]| \geq k\sigma\} = 1/k^2.$$

Now assuming further that the probability distribution has equal probability on each side of the mean,

$$\Pr\{X - E[X] \geq k\sigma\} = 1/(2k^2)$$

and

$$\Pr\{E[X] - X \geq k\sigma\} = 1/(2k^2).*$$

So, given the mean $E[X]$ and the variance σ^2, the distribution function may be reconstructed by varying k in reasonably small steps over an appropriate range. In the program written for the analysis this is done automatically for each subsystem and then, for any specific values of the input parameters, summary information about the queue is printed out in the form of the average number of each priority in the system, the total average system wait, the variance of the system wait for each priority, the (approximate) probability distribution for the three priority delays.

The distributions for the three priorities must then be combined in order to obtain the probabilities for the total process. This is done by the usual mixing procedure as follows. If the individual probabilities for the k^{th} priority are denoted by $\{p_i(k),\ 1 \leq i \leq 20\}$, and the combined distribution by $\{C_i,\ 1 \leq i \leq 40\}$, then

$$C_i = (a_1/a)\, p_i(1) + (a_2/a)\, p_i(2) + (a_3/a)\, p_i(3).$$

*This assumption may be changed by altering the value of an appropriate parameter in the program.

APPENDIX D

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APPENDIX E

GLOSSARY

ACCESS - Afloat Consumption, Cost and Effectiveness Surveillance System.

A computerized system which collects and summarizes basic data generated in the normal course of supply and fiscal operations.

AFB - Air Force Base

AFS - Fleet Issue Ship, an element of the Mobile Logistics Support Force.

AMF - Air Mail Facility

ANORS - Anticipated Not Operationally Ready Supply. Refers to the operational status of aircraft.

APA - Appropriation Purchase Account.

Consists of the following appropriations:

(a) Weapons Procurement, Navy (WPN)
(b) Aircraft Procurement, Navy (APN)
(c) Ship Construction & Conversion, Navy (SCN)
(d) Other Procurements, Navy (OPN)

APOD - Aerial Port of Debarkation

APOE - Aerial Port of Embarkation

APP - Air Parcel Post

AUTODIN - Automated Digital Information Network

Provides high speed data transmission and switching capabilities linking all major supply data processing installations.

CASREPT - Casualty Report

Report submitted by operating unit indicating reduced capability of a system and degree of mission empairment. Used colloquially in reference to a particular piece of equipment which is not operationally ready.

CID - Component Identification Number

CNM - Chief of Naval Material

COD - Carrier on Board Delivery

Air delivery of material from a shore point to an aircraft carrier at sea.

COG SYMBOL - Cognizance Symbol

A two position code prefixed to the Federal Stock Number to identify the type of material and the inventory manager. (See Table II-1 for description of cognizance symbols).

COMCRUDESLANT - Commander, Cruiser and Destroyer Force, Atlantic Fleet

COMNAVAIRLANT - Commander, Naval Air Force, Atlantic Fleet

COMPHIBLANT - Commander, Amphibious Force, Atlantic Fleet

COMSERVFORSIX - Commander, Service Force, Sixth Fleet

COMSIXTHFLT - Commander, Sixth Fleet

CONUS - Continental United States

Convolution - Process to determine the probability that two or more independent events occur in a given interval.

Coordinated Shipboard Allowance List (COSAL) -

Defines Specific Repair parts etc. required to support both individual components and the ship as a whole.

COSAL - See Coordinated Shipboard Allowance List.

DCSC - Defense Construction Supply Center. (See Defense Supply Agency)

Defense Supply Agency -

Centrally manages items common to all Military Services.

Depth - The stocked quantity of an individual item. (See also Range)

DESC - Defense Electronics Supply Center. (See Defense Supply Agency)

DISC - Defense Industrial Supply Center. (See Defense Supply Agency)

DSA - See Defense Supply Agency.

DTO - Direct Turn Over.

An item ordered from sources external to the ship for immediate or planned use.

EAM - Electric Accounting Machine.

EIC - Equipment Identification Code.

Electronics Supply Office -

The inventory manager responsible for Navy secondary electronics items.

EOQ - Economic Order Quantity. The optimal amount of material to purchase at one time.

ESO - See Electronics Supply Office.

Federal Stock Number -

A 12 digit number which identifies each supply item from all other items in the supply system. It is normally preceded by a cog symbol.

FILL - See Fleet Issue Load List.

Fleet Issue Load List -

Material requirements, in range and depth, to resupply deployed units for a 90 day endurance period.

Fleet Material Support Office -

Central design agency for uniform data processing systems for Navy supply, principal Navy supply operations analysis group, financial manager of 9-cog material.

FLSIP - Fleet Logistics Support Improvement Program.

FMSO - See Fleet Material Support Office.

FPO - Fleet Post Office. The official address for all ships' mail. There are two, one in New York and one in San Francisco.

FSN - See Federal Stock Number.

ICP - See Inventory Control Point.

Incremental - A change, either positive or negative, in the value of the independent variable; also, the corresponding change in the value of the dependent function.

Initial Stock List -

Defines what repair parts are carried aboard new construction ships or ships undergoing major conversion.

Inventory Control Point -

Responsible for program support of assigned equipment or components and the inventory management of assigned items. NAVSUP has three ICPs: Electronics Supply Office, Ships Parts Control Center, and Aviation Supply Office (not discussed in this study).

IPG - See Issue Priority Group.

ISL - See Initial Stock List

Issue Priority Group -

A categorization of three or more individual requisition priority indicators. Specifically, IPG I includes priorities 01, 02, 03; IPG II includes priorities 04, 05, 06, 07, 08; IPG III includes 09, 10, 11, 12, 13, 14, 15.

MAC - See Military Airlift Command.

MADT - Mean Administrative Delay Time. All delays not accounted for by MTTR and MSRT.

Marginal - See Incremental.

MATCONOFF - Material Control Officer. Acts as a liaison between a ship having a high priority requirement and other Sixth Fleet ships that might be able to satisfy it.

Matrix - An ordered array of numbers.

MCAS - Marine Corps Air Station.

MDCS - Maintenance Data Collection System, a part of the 3-M system.

Mean - Arithmetic average.

MED - Mediterranean Sea. The operating theater of the Sixth Fleet.

Military Airlift Command - Provides airlift services to overseas destinations for the four military services.

MILSTEP - Military Standard Evaluation Procedure.

MLSF - Mobile Logistic Support Force. Supplements a ship's endurance by providing a source of fuel, ammunition, provisions, frequently used repair parts, general consumable items and certain insurance items not carried aboard combatants.

3-M - Maintenance and Material Management. Collects data on corrective maintenance actions. This serves as a basis for the S^4 demand generator.

MOM - Military Ordinary Mail. A class of parcel mail service.

MPN - Military Pay, Navy. Funds used to pay military salaries.

MRRT - Mean Requisition Response Time. Average length of time to satisfy a given requisition.

MSRT - Mean Supply Response Time. Average length of time required to assemble all the spare parts required in a given corrective maintenance action.

MTBF -	Mean Time Between Failure. Average length of time between consecutive failures for a given piece of equipment.
MTTR -	Mean Time to Repair. Average amount of time the mechanic spends on the corrective maintenance action. This includes diagnosis and actual repairs.
NAS -	Naval Air Station.
NAVAIR -	Naval Air Systems Command. Responsible for the design, production and installation of major aeronautical equipment.
NAVCOMSTA -	Naval Communications Station. Responsible for receipt, transmission and dissemination of Naval message traffic.
NAVELEX -	Naval Electronics Systems Command. Responsible for the design, production and installation of major electronic equipment.
NAVORD -	Naval Ordnance Systems Command. Responsible for design, production and installation of expendible ordnance and major ordnance equipment.
NAVSHIPS -	Naval Ships Systems Command. Responsible for the design, production and installation of ships, major ships' equipment, small boats and landing craft, and nuclear propulsion components.
NORS -	Not Operationally Ready Supply. This refers to the operational status of an aircraft.
NRFI -	Not Ready for Issue.
NSA -	Navy Stock Account. Finances the ICP procurement of most Navy centrally managed spares. The appropriation used for reimbursement when DSA and GSA items are placed in the Navy's retail inventory.
NSC -	Naval Supply Center.
NSF -	Navy Stock Fund. (See NSA)

NSY - Naval Shipyard.

Null Hypothesis -

In a statistical test, this is the supposition which is asserted. It is then up to the data to accept or reject the "null hypothesis".

O&M,N - Operation and Maintenance Funds, Navy. Funds managed directly by the end user and intended for the operation and maintenance of existing equipments and systems. This is contrasted to the appropriations for research, procurement of new equipment and military pay.

OPN - Other Procurement, Navy. Funds for the procurement of high value ships' spares, repair parts and other items of a "permanent" nature. This does not include ships, aircraft or weapons.

OPNAV - Office of the Chief of Naval Operations.

OPTAR - Operations Target. The amount of funds given to a unit to finance operations. The OPTAR Log is a record of all expenditures against these funds.

OSI - Operating Space Item.

Parametric Analysis -

Systematic change in independent variables and constants to establish their effect on the dependent variable.

PCC - Postal Concentration Center.

POE - Point of Entry. The initial place where a requisition enters the supply system.

Principal Items -

End items of equipment such as ships, aircraft, or missiles.

QUICKTRANS - Navy managed commercial airline service.

Range - Number of different items stocked. (See also depth)

Retail Inventory -

Inventory wholly under Navy control.

RDT&E - Appropriation for Research, Development, Test and Evaluation.

RFI - Ready for Issue. Refers to the condition of an item.

Safety Level - The quantity of material, in addition to the operating level of supply, required to be on hand to permit continued operations in the event of minor interruptions of resupply or unpredicted fluctuations in demand.

Secondary Items -

All items which are not primary items, i.e., repair parts, components and general use consumables.

SIM - Selected Item Management. An inventory control principle which, in non-automated ships, focuses management attention on the small percentage of items that experience the majority of on-board demands for material.

SMOLANT - Ships Material Office, Atlantic.

SPCC - Ships Parts Control Center. Responsible for the management of ships' items (Hull, Mechanical, and Electrical) conventional ammunition, non-expendible ordnance items, and construction equipment items.

S^4 - Ships Supply Support Study.

TOR - Technical Override. The quantity of material required by the Hardware Systems Command to be on board in support of an equipment as a vital insurance item.

TYCOM - Type Commander. The Commander of a specific group of ships or units. (See COMCRUDESLANT, COMPHIBLANT, and COMNAVAIRLANT).

UICP - Uniform Inventory Control Program. A series of computer programs and manual routines used for purchase, requisition processing, requirements determination, load list preparation and technical data recording.

Variance - A measure of the dispersion of the data.

Wholesale Inventories -

Quantities of DSA owned material which the Navy Stock Points use to satisfy their customer requirements.

APPENDIX F

INDEX TO S^4 TECHNICAL MEMORANDA

Many of the 140 Technical Memoranda issued during the S^4 Study contain detailed information which confirms or supplements that in the Final Report. These can provide future researchers with data directly pertinent to supply support in the Navy, especially the Sixth Fleet. Single copies of memoranda of interest can be obtained from:

S4 Maintenance Group (Code 971)
U. S. Naval Fleet Material Support Office
Mechanicsburg, Pennsylvania 17055

indicating the appropriate date and code at the right below.

Availability, Effect of Routine Resupply on	26 Jan 73 L 23 Sep 72 P
Availability, ICP	24 Mar 72 L 16 Feb 72 E
Availability, Shipboard	18 May 72 P 17 May 72 E 24 Mar 72 L 29 Dec 71 G
Backorder, DSA	17 Apr 73 R
Backorder, Navy	14 Dec 72 G 7 Dec 72 G
Converter	2 Oct 72 K
Cost Data, Navy Supply Operations	8 Jun 73 L
Demand Data	28 Aug 72 G
Demand Data, Slow Moving Items	17 Apr 73 R 15 Mar 73 R 14 Dec 72 R
DSC Performance Data	17 Apr 73 G
Effectiveness Data by Cog	5 Oct 72 G 29 Dec 71 G 23 Nov 71 E

Inventory, Shipboard, Dollar Value of	9 Nov 72 P
	18 May 72 P
Mark I Inventory Simulation:	
ICP Simulator Results	14 Aug 72 R
Inherent Assumptions	12 Jul 72 P
Ashore Simulator, Evaluation of Assumptions	24 May 72 R
MLSF Simulator, Results	10 May 72 P
Ashore Simulator, Demand Generator	3 May 72 R
Supply System Simulator, Initial Experiments	7 Apr 72 P
MLSF & Shipboard Simulators, Modifications	20 Dec 71 P
ICP Simulator, Requisition Processing	17 Nov 71 G
Modification to 30 August 71 E	6 Oct 71 P
Demand and Inventory Data	5 Oct 71 E
Ashore Simulator, Gross Requisition Effectiveness	28 Sep 71 E
System Design	30 Aug 71 E
Ships & Activities to be Simulated	25 Aug 71 L
ICP Simulation Model	6 Aug 71 E
Demand Generation for Non-Movers	5 Aug 71 E
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Stock Point Simulation Model	19 Jul 71 E
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Definition of Terms: Inputs, Events, Outputs, Variables	9 Apr 73 P
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